Journal of the Institute of Petroleum

VOL. 41 DECEMBER 1955 No. 384

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Published by the Institute of Petroleum 26 Portland Place London W1

Printed in Great Britain by Richard Clay and Company Ltd Bungay Suffolk

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THE INSTITUTE OF PETROLEUM

A General Meeting of the Institute of Petroleum was held at the Institution of Mechanical Engineers, Storey's Gate, S.W.1, on 30 June 1955, the Chair being taken by the President, Lt.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc.

The Chairman introduced Messrs M. K. McLeod, T. B. Rendel, A. J. Blackwood (deputizing for Dr W. J. Sweeney), and V. G. Raviolo (deputizing for E. S. MacPherson), who read the following four papers, respectively.

THE CO-ORDINATING RESEARCH COUNCIL *

By M. K. McLEOD †

WHAT IS THE CRC?

THE Co-ordinating Research Council, familiarly known as the CRC, is an expression of the desire of two great industries, the automotive industry‡ and the petroleum industry, to serve their mutual customers well. The CRC consists of more than 700 engineers, ranging from young men just through engineering school to heads of the research sections of large corporations working in over 100 research laboratories in the two industries. Most of all, the CRC is physical evidence of the mutual recognition by these industries of the necessity of working together for the common good.

The purposes and objectives of the CRC as outlined in the certificate of incorporation are as follows:

> "To encourage and promote the arts and sciences by directing scientific co-operative research in developing the best combinations of fuels, lubricants, and equipment powered by internal combustion engines; and afford means of co-operation with the Government on matters of national interest within this field."

This formal statement is not a dry collection of words created by a committee sitting around a conference table. Rather, it is a living expression of a basic principle which has been moulded through the years from the thoughts, words, and deeds of the hundreds of engineers who have worked on fuel–lubricant–engine problems.

GROWTH OF CO-OPERATIVE IDEA

The concept of co-operative research cannot be traced back to a single individual or a single group, but it is rather the result of a gradual evolution. In the earliest days, the pioneers in scientific research were individuals, but with the development of applied research by large commercial organizations, research work became a matter of team work. Co-operative research among men working for different groups within a given industry, and even men working together within different industries, has come about within the past half-century with the growth of large-scale applied research. The highest form of co-operative research is the gathering together in a common place of men representing different companies and different industries to jointly conduct extensive experiments, and is just now coming of age.

Individual initiative and research cannot be replaced by co-operative effort. Individual or competitive research work will always provide the real incentive to produce better materials and equipment. Co-operation takes advantage of the information made available by individuals, and, by the alchemy of group effort, promotes and enhances the value of the research.

The development of co-operation in engine–fuel research parallels the individual development of the automotive and petroleum industries. As the automobile moved out of the category of a novelty and became an integral part of living, societies were organized to provide meeting places where technical men could meet and discuss the results of their work and their views on future developments. In the U.S.A., the Society of Automotive Engineers (SAE) was organized in 1905. Just two years later (1907) it is recorded in the *SAE Journal* "engineers began to be worried about fuels because, they said, there is not enough gasoline to go around and what are we going to do when the supply runs out?"

During the first years of the automobile, gasoline was a waste product from the refining of kerosine and contained as much volatile matter as could be used. The rapid increase in the number of automobiles in use brought about a situation where demand began to push supply and quality began to change. In the period from 1914 to 1919, for example, automobile registration in the U.S.A. increased more than 300 per

* MS received 21 April 1955.
† Manager, Co-ordinating Research Council, Inc.
‡ The term "automotive industry" is used in its broadest sense, and includes the motor car industry, the aircraft and diesel engine industries, the airframe industry, and the related accessory manufacturers.

cent, gasoline production increased 200 per cent but crude oil production only 42 per cent. Efforts to meet the increasing demand required deeper and deeper cutting into the kerosine range, with constant increase in end point and reduction in anti-knock quality. Complaints led to a national conference held early in 1917 at the Bureau of Standards. Automotive engineers in attendance at that conference pointed out that, if they could know somewhat in advance the character of the gasoline which would be available, they could succeed, within reasonable limits, in adapting their engines to it.

C. F. Kettering, in his presidential address to the SAE in 1919, stated "I think it is only well at this time we should begin to think in terms of the fuel question, not only from a supply and demand point of view, but also from an efficiency standpoint. We engineers have a lot to do from the latter standpoint; we have hardly touched the subject as yet. . . ."

The same general thinking is reflected in the remarks of T. A. O'Donnell, president of the American Petroleum Institute (API) at its first meeting in 1919. "We have arrived at the era of community effort. The individual efforts of a century ago served fairly well in meeting the demands of the times. We are rapidly approaching, if we have not already reached, a point where the individual effort in the oil industry will find its best exemplifications in co-operative action. . . . The producer of petroleum is, after all, a trustee administering a diminishing output on behalf of the population as a whole. Deliberate waste and inefficient handling of the product should not be tolerated by the industry. Intensive and constructive investigations can and should be undertaken in an effort to determine what can be done that will more efficiently administer the trust."

The first meeting between representatives of the automotive and petroleum industries was held in June 1919, when seven men from each industry laid the foundation for a motor fuel research programme.

At a conference held later in the year, it was generally agreed that the numerous problems involved would require thorough and extensive research. Resolutions were adopted providing for the maximum utilization of the available laboratory apparatus and other research facilities, and it was agreed that if these facilities were not adequate for solution of the problems in hand, ways and means for securing additional facilities of a more centralized nature would be given careful consideration. It was the consensus that steps should be taken to bring the technical men of both industries into contact, and that these men would be assured of the hearty support of the executives through whom their recommendations would be put into effect.

At the 1920 Annual Meeting of the API, C. F. Kettering, discussing gasoline consumption and the automotive industry, stated "I do not believe that there have been very many serious thoughts given to the question of the adaptability of our present fuels to the gas engine. . . . We have talked about this a great deal with the automotive people, and they have not bothered with the fuel question because of all they have got to do to make the motors. You fuel fellows are not interested in the motor business. All you have to do is to sell the fuel, so this problem has been sort of thrown out in the middle of the road, and it has been nobody's responsibility. . . . We cannot do the things we want to do with the automobile engine until we get the proper fuel worked out and we have difficulty getting fuel work done before we get the proper engine. We must carry the movement in co-operative effort by the API, the automotive industry, and the chemical societies."

ORGANIZATION OF CFR

The formal organization of what is now the CFR Committee began in the early part of 1921, when a meeting of a "Joint Technical Advisory Committee on Efficient Utilization of Petroleum Products" was called by V. H. Manning, Director of Research for the API, to "discuss the joint responsibilities of petroleum and automotive industries in regard to present and probable future supplies of motor fuel." At that conference it was agreed that each industry would work on the relation of volatility and fuel consumption and also the relation of volatility and yield of gasoline per barrel of crude oil. Here is seen for the first time the joint approach to the engine–fuel problem. The SAE, which was at that time sponsoring experimental work on fuel economy at the National Bureau of Standards, suggested that its research programme be broadened. The National Automobile Chamber of Commerce and the API agreed to share in the sponsorship of this joint research, and promises of support and co-operation were made by individual companies.

Such were the beginnings of co-operative engine–fuel research. Chemists, physicists, and engineers from automotive, petroleum, Government, and university laboratories were organized under the broad technical direction of a small group (CFR Steering Committee) which was appointed to confer on the programme and pass on the results.

This four-sided combination continued for many years, with the National Automobile Chamber of Commerce and the API, representing the two industries, furnishing the funds, the SAE administering the funds and watching the technical programme, and the Bureau of Standards carrying out most of the research work.

The early co-operative work of the CFR Committee was concerned almost exclusively with the volatility of gasoline. This was natural, since the increasing demand for gasoline occasioned by the phenomenal growth of the motor car industry called for modifications of gasoline composition, including the use of heavier materials to increase availability. It was soon recognized that, to supplement the Bureau of Standards' investigations, there should be co-operative field test programmes conducted by the laboratories of the individual companies. Thus, one of the basic principles of CRC activity was established—that field service tests are necessary to demonstrate the nature

of the problem and the general parameters which must be studied in more detailed laboratory investigations.

Other volatility factors, such as crankcase oil dilution and difficulties with starting, were also investigated. The conclusions of the test programme carried out at that time still hold good today. The increasing yield of gasoline made it no longer necessary to use the heavy ends, and increased the amounts of lighter stocks which had excellent characteristics for a motor fuel from the standpoint of combustion. With the use of the higher volatility motor fuels, the problem of vapour lock came to the fore. Considerable basic research was conducted by the U.S. Bureau of Standards under CRC sponsorship. In addition, survey data and a correlation of fundamental data with actual vehicle performance were obtained by the CFR.

With the aid of the knowledge obtained from co-operative activities, the automotive industry was simultaneously developing competitively a variety of manifold designs, carburettors, crankcase ventilation, etc., to permit the automobile to utilize fuels of the type which would be made available by the petroleum industry.

As the work on volatility progressed, another problem—detonation—appeared on the horizon. As early as 1918, both Ricardo in England and Midgeley and Boyd in the U.S.A. had been devoting a tremendous amount of research to the subject of "knocking combustion" in spark-ignited gasoline engines and the limitations which this imposed on engine performance. In 1926 the CFR Steering Committee noted that the lack of a generally accepted method for measuring the anti-detonating qualities of gasoline was acting as a serious handicap to systematic research in this field. It agreed, therefore, to incorporate in its programme a survey of the methods then in general use, and eventually to undertake a programme to develop a commonly accepted method.

During 1927, two co-operative programmes were initiated by private companies. The results of these test programmes indicated considerable divergence among the various methods for measuring the anti-detonation properties of a number of fuels. The CFR Steering Committee, in 1928, agreed to establish a Sub-committee on Methods of Measuring Detonation with the assignment of developing "an apparatus and method for making knock ratings, together with suitable reference fuels which would enable everyone doing knock testing to talk the same language."

This was another of the fundamental steps taken in the development of CRC—the decision to build a special co-operative test engine. By far the greatest amount of "knock" research had been conducted in actual commercial engines on the dynamometer or in vehicles on the road. Certain investigations, notably those of Ricardo in England and Kettering and Edgar in the U.S.A., had shown that test data could be obtained in special single-cylinder test engines, but the result from the various test engines differed widely.

The Sub-committee quickly agreed to design and build an engine suitable for knock testing, so that the experimental work of everyone could be carried out on a common basis. This vital job was taken on by H. L. Horning and done at the Waukesha Motor Company. The development of the test engine proceeded very rapidly. Within a two-month period after the design requirements were established in November 1929, a prototype engine was running. A group of about twelve engines was built, and after much experimental work and co-operative testing the CFR Committee, at its meeting on 14 September 1931, approved the apparatus and procedure for measuring the knock characteristics of gasoline in terms of octane numbers. The octane number scale was based on a proposal made by Dr Graham Edgar in 1927.

This test method, including the octane number scale, was published by the American Society for Testing Materials (ASTM) in 1932 as a "Proposed Method for Determination of Knock Characteristics of Motor Fuels." This same method, with minor modifications to give greater reproducibility and repeatability, exists today as ASTM Method D908–53.

At this stage of the proceedings it became apparent that there was an urgent need to correlate the newly developed laboratory octane numbers with those obtained in actual service on the road, and the famous series of Uniontown tests was inaugurated. In this co-operative work an extensive series of knock ratings was made in cars by representatives of twelve automotive and petroleum laboratories, as well as the Bureau of Standards and Yale University. In this project, groups from different industries gathered at a common place and jointly engaged in experimentation, not only to develop methods for measuring the knock ratings of cars on the road, but also to rate a comprehensive series of fuels of widely different types in a large number of different makes of automobiles. Following that, with some changes in representatives participating, the group gathered at the Waukesha Motor Company, builders of the laboratory engine, and worked out by experience, using the same fuels, modifications of the knock test apparatus and procedures to give the best possible correlation between the laboratory ratings and the road ratings just obtained at Uniontown.

Accurate prediction of road performance of knock was not yet possible. Accordingly, another and still more extensive series of co-operative tests was run at Uniontown in 1934—this time with participants from England, France, and Canada—for the purpose of checking the continued correlation of the road results with ratings by the Motor Method. Still other co-operative correlation tests were run later, notably at San Bernardino in 1941, where twenty-four test cars were driven over 100,000 miles. The results of these as well as subsequent road tests have shown that no single laboratory method completely evaluates a gasoline for knock in all its uses. These road test programmes did much to develop a generation of petroleum and automotive engineers who understood each other's technical problems.

It was natural that the aircraft engine industry and

the air arms of the Government should be interested in the possible application of the new motor fuel test method to the evaluation of aviation fuels. While in the automotive field the driving force was the possible shortage of fuel and the wastage of natural resources until availability and requirements were brought into balance, in the aviation field the prime factor was the ability to develop the maximum power from a given engine size, using the minimum weight of fuel. This need called for an improvement both in the fuel quality and a change in engine design to take advantage of the improvements in the fuel, and resulted in the formation of the CFR Aviation Gasoline Detonation Subcommittee.

The advent of aviation fuels within the structure of the CFR introduced another facet of co-operation. In the motor fuel research programmes the main research effort was being carried out in the laboratories of the co-operating industries, which were setting up fuel and engine testing laboratories and the organizations to carry out field service tests. The amount of fuel required for test purposes was relatively small. The same types of facilities were not available in the aviation industry. In addition, the fuel requirements were very large. This led to a mechanism being established by which the engine companies could supply the engine test time and the petroleum companies could supply financial support to cover the cost of the large amounts of fuel involved.

The diesel engine, in its early days, was a relatively large, low-speed engine and was not especially critical to fuel type. By the early 1930s, however, there was a definite trend by some of the engine manufacturers to higher engine speeds, and it became evident that fuel characteristics would play an important part in its future. A number of early investigations had shown the importance of the ignition quality of diesel fuel. A relatively small number of the diesel engine manufacturers seemed to be interested in this high-speed use of the diesel engine, but the diesel industry, as a whole, did not feel that a co-operative research programme was of sufficient interest to be worthwhile. A volunteer group of men from the petroleum industry, from the small high-speed section of the diesel engine industry, and from two universities interested in the problem, banded together to carry out co-operative experiments on the most promising methods of measuring ignition quality. In a short period of time another fuel test engine was developed, utilizing a high turbulence cylinder head. By 1937, a procedure for measuring ignition quality had been worked out and an extensive field testing programme was to be conducted. At this point, the CFR Committee was convinced of the importance of the work and lent its name and support in obtaining the co-operation of other petroleum and engine companies in carrying out the work involved in establishing a correlation between the laboratory tests and the field test programme. Thus, another milestone in CFR history was passed with the introduction of the diesel industry to the value of co-operative research.

FORMATION OF CRC

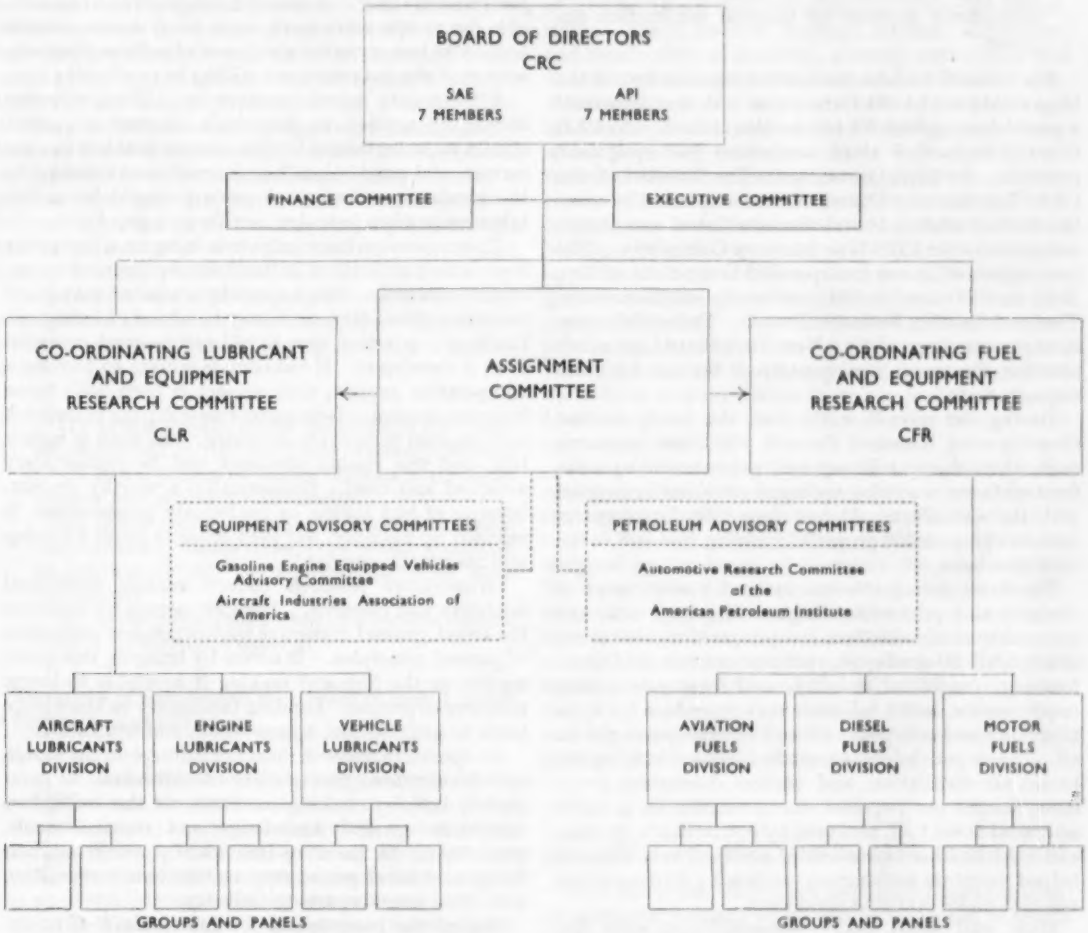
By 1940, CFR had grown both in size and stature. Its growth from a membership of 20 men in 1922 to a membership of 980 men in 1940, and a corresponding increase in the technical material created from 1000-page copies in 1922 to 120,000 in 1940 was a valid indication of the recognition of the value of CFR to both industries. The vastly increased secretarial function had entailed for the SAE greater expense than had been foreseen, much greater than the specific contributions of the two industries, and quite clearly indicated the need for a more formal arrangement for supporting the co-operative research function.

A new and very important function, that of acting in an advisory capacity to the military services, had been added to the work of the CFR Committee, which also increased the burden on the committee secretariat. At the request of the military services, a separate committee, the CFR War Advisory Committee, composed of technical representatives of both the automotive and petroleum industries, was organized to recommend programmes for investigating the fuel requirements of military vehicles. Because of the shortage of trained technical men in the military services, the CFR Committee, in addition to planning the research programme, also assisted in carrying out the test work on a variety of subjects, including knocking, cold starting, and vapour lock.

The subject of co-operative study of lubricating oil had not progressed at the same speed as had the fuel studies. Since there was no imminent shortage of material, there was a relative lack of urgency. In addition, the evaluation of the effects of lubricating oils is a very complex affair requiring long term tests. There was no incentive for active co-operative work, and for a considerable time the necessary improvements were left to competitive research. However, during the 1930s the importance of lubricating oil quality was emphasized as engine performance was being increased. By 1940 the introduction of the "heavy-duty" lubricants was causing concern, since there was no general acceptance of methods for evaluating their performance. With the introduction of the hypoid axle, the evaluation of gear lubricants was also becoming important, and it was evident that extensive work would be required to develop techniques for evaluating gear oils.

The need for direction of the co-operative activity in the lubrication field, the necessity for expanded effort in assisting the military services, the greatly increased cost to the SAE for supporting the secretariat, the advantage of having joint research embodied in a single organization capable of entering into contracts with the military services were all instrumental in leading to the decision to establish a separate co-operative activity to handle engine–fuel–lubricant research.

As a result of numerous discussions among representatives of the petroleum, automotive, aviation, and diesel engine industries, and between the API and



NOTE: This chart indicates that projects originating in either of the technical Committees, the Advisory Committee, or at the suggestion of outside organizations, are considered by the Assignment Committee and assigned to the appropriate technical Committee for carrying out the necessary work and for the preparation and issuance of reports.

FIG 1

FUNCTIONAL CHART FOR THE CO-ORDINATING RESEARCH COUNCIL

the SAE, the Co-operative Research Council was organized in April 1942, to:

> ". . . direct co-operative research in developing the best combinations of fuels, lubricants, and equipment powered by internal combustion engines."

The Council became the parent organization of the long established CFR Committee. It also organized a parallel committee for lubricants research—the CLR Committee—and a third committee for equipment research—the CER Committee. The function of the CFR War Advisory Committee was expanded to cover the field of lubricants and was established as a fourth committee—the CRC War Advisory Committee. The new organization was incorporated in the State of New York on 13 December 1943, under the modified name, The Co-ordinating Research Council. The modification in name was dictated by a New York State Law which reserves the word " co-operative " for use by farm organizations.

During the second world war, the newly formed Co-ordinating Research Council was called upon by more than thirty military and government agencies for assistance in solving technical problems connected with the war effort. At one stage 1500 investigators were working on 300 projects involving fuel and lubricant problems.

The work during the war covered a wide range of projects and products. Engine oil groups attacked the problems of oxidation, low-temperature characteristics, SAE 50 grade oil, rust preventives, additives, foaming, oxidation stability, and two-cycle engine requirements, and a full-scale test procedure for aviation oils was developed. Other CRC groups sought an all-purpose gear lubricant, studied vapour lock, equilibrium air distillation, and various detonation problems, sought the required characteristics for a single universal diesel fuel, analysed hydraulic fluids, greases, and cold-weather operation of military vehicles, and helped maintain satisfactory service for civilian motor vehicles under wartime conditions.

How well these many responsibilities were discharged is indicated in some measure by the receipt by the Council of three awards for meritorious wartime service:

> Ordnance Distinguished Service Award
> Naval Certificate of Achievement
> Naval Ordnance Development Award

ORGANIZATIONAL STRUCTURE

The ending of the second world war and the resumption of peacetime activities gave an opportunity for a reappraisal of the CRC structure—an opportunity for a reorganization to better fit the CRC to carry out its enlarged and more varied responsibilities to the co-operating industries.

Basic and fundamental principles governing inter-industry co-operative research had been developed during the formative years of CFR and CRC. These principles were to form the base upon which an organizational structure was to be built.

Mutual interest in the problem is essential in any joint undertaking. A research programme to be suitable for co-operative work must be of direct concern to the two industries involved, and of sufficient importance that the industries are willing to pay for it.

A frequently asked question is, " What criterion should be applied to determine whether a project should be undertaken? " The answer to this is simple, certain, and practical, although sometimes shocking to the idealist questioner. A project should be undertaken only when industry is willing to pay for it.

That necessary knowledge is lacking on a particular topic is no justification, in itself, for carrying out co-operative research. The knowledge required may be of limited applicability, or it may be ahead of industry's thinking; in either case it will not be used or useful even if developed. If industry is willing to pay for a co-operative project, that project is born with three inherent elements of successful research; the knowledge it is planned to provide is needed, that need is widely felt, and the results obtained will be immediately accepted and used. Occasionally, a worthy project, because of bad timing or inadequate presentation, is rejected by industry, but such projects profit by delay and eventually survive.

Co-operative research cannot replace individual initiative and research. The CRC serves by fostering the broad, general, collective application and utilization of general principles. It serves by bringing this information to the fore and making it available to larger numbers of people. Lending familiarity to knowledge leads to assimilation, appreciation, and utilization.

Co-operative research must not infringe on the design and development prerogatives of individuals or companies, but, by making available to the individual companies general knowledge and research tools, must better fit them to individually carry on their design and development responsibilities in competition with their counterparts in industry.

One of the basic tenets for the conduct of co-operative research is the principle of promoting freedom of technical thought and action. Co-operative research, lacking the incentive of individual gain, needs inspiration and guidance to spur flagging interest and encourage advances. It is leadership from within and not direction from without which must supply the inspiration and guidance.

Utilizing the foregoing principles and philosophy, the Co-ordinating Research Council organizations has been designed to afford a straightforward method of accepting problems, carrying out the necessary work to obtain the answer, and distributing the resultant information to all those interested.

A functional chart, outlining the relationship of the various committees, and illustrating how projects which have been proposed for co-operative action are assigned to the appropriate technical committee and reports on the results issued, is shown in Fig 1.

Reporting to the Board of Directors, which has responsibility for all CRC activities, are the two technical committees, the Co-ordinating Fuel and Equipment Research (CFR) Committee and the Co-ordinating Lubricant and Equipment Research (CLR) Committee, which supervise the technical activities of the Council, and the Assignment Committee, which has been designated by the board of directors as the agency to accept, approve, and assign projects for the Council. The Assignment Committee acts as the co-ordinating agency between the technical committees and the equipment and petroleum industries and determines whether a project which has been proposed as a Council activity will be supported by the co-operating equipment and petroleum industries with the necessary funds and personnel to carry out the work.

In its consideration of the projects which have been presented to the Council, the Assignment Committee evaluates the problems in the light of the following criteria:

(1) Is this project within the scope of the Council as defined in its Certificate of Incorporation?
(2) Is the project of mutual interest to the automotive and petroleum industries?
(3) Is the project of sufficient interest to ensure that necessary funds to support it and personnel to execute it will be forthcoming from both industries?
(4) Is the project supported by a specific request from a Government agency?

The scope of the Council mentioned in item 1 above is interpreted as follows:

(1) Research as applied to any activity of the CRC means the determination of the effect of the variables, (*a*) equipment design, (*b*) fuel or lubricant characteristics, (*c*) operating conditions, on the combined performance of the fuel and engine or of the lubricant and equipment.
(2) While research techniques are necessary for the carrying out of research projects, the Council is a research organization and does not prescribe methods of test nor engage in the writing or promulgation of specifications for commercial use.

Projects which are approved are assigned to the CFR or CLR Committee for prosecution.

The CFR and CLR Committees supervise the technical activities of the Council and are responsible for maintaining these activities within the purposes and objectives of the Council. Membership is selected from representatives of organizations which contribute adequate financial support, research facilities, or technical data to the work of these committees, or persons who have training and experience of special value in the work of the committees. The CFR and CLR committees have a number of divisions or groups responsible to them, and may organize other divisions or groups needed to carry out approved projects.

It was found in the CFR, and subsequently in the CRC, that the best unit of organization is a small group of five to fifteen men investigating a specific assignment. Every member, through interest, knowledge, and availability of facilities, actively contributes and is expected to act on the basis of his technical convictions rather than as an advocate of the policies of his company. The most active CRC projects are those which have been carried out in the individual laboratories of the co-operating group members, and the results of the experiments freely discussed and analysed by the members on the basis of their individual beliefs. In initiating a new project, a leader may be appointed to organize the working group, but when the personnel of the group has already volunteered, the group will elect its own leader. These leaders, possessing the confidence of their groups and the knowledge of their specific subjects, have so well lived up to their responsibilities that they and their groups form the surest foundation for effective co-operative research in the CRC.

The technical reports prepared as a result of the activities of the various groups, after approval by the appropriate division, are carefully reviewed by the CFR or the CLR committee. These committees have been assigned by the Board of Directors the responsibility for the preparation of technical reports and for ensuring that they meet the technical standards developed by the CRC. These reports are then made generally available to the automotive and petroleum industries by release to the SAE and the API. Thus, non-participating companies, as well as those which were actively engaged in work on a particular project, may benefit from the research investigations.

BENEFITS FROM CO-OPERATIVE RESEARCH

Over the years, there have been major benefits from co-operative research which can be measured in terms of the end result, which is improved utilization of petroleum products in engines. Other benefits, in some ways even greater, cannot be measured in specific values, but are reflected in the more general terms of friendliness, understanding, and progress. A few may be listed as follows:

(1) From a purely technical standpoint, early contacts between automotive and petroleum engineers had a definite influence on the establishment of fuel research laboratories. With one or two exceptions, there were in 1921, so far as is known, no engine testing laboratory facilities in the petroleum industry, and perhaps only one or two in the automotive industry, equipped for the effective study of the relationship of fuel characteristics to engine performance. Today there is no large or medium size company in the oil industry without such a laboratory and very few

engine companies of any size who do not actively participate in this form of research.

(2) Through co-operative efforts, and as a logical part of research investigations, a number of research techniques have been developed which can be used by individual companies in evaluating their own products. These techniques are not to be considered as specifications or standards, since the CRC does not issue specifications or standards. In employing these techniques a common understanding of the meaning of terms has been developed and a common language made available for industry use.

(3) One of the major benefits of co-operative work has been the recognition by the automotive industry of the fact that petroleum products are as much a part of engine design as any of the other materials, such as steel. There is an understanding on the part of the automotive engineers of the necessity of the engine being able to use a range of petroleum products, and an understanding on the part of the petroleum industry of the improvements in engines that can be brought about as a result of improvements in fuel or lubricant quality. There is general understanding by both industries that the optimum combination will involve compromises, and that there can be no such thing as a perfect engine or a perfect fuel.

(4) By participating in co-operative programmes, which are in no way concerned with competitive aspects, newly established companies or companies embarking on a new phase of interest have been able to learn from the past experience of those who have been conducting research along such lines for a longer period. Conversely, the older companies have the benefit of a fresh viewpoint.

(5) Many of the joint programmes have served as effective " on the job " training for the younger generation of engineers. In the various co-operative groups these young men have been encouraged to participate fully in planning programmes, carrying out test work, and analysing the resultant data. While doing this, they have not only been able to have a frank interchange of ideas with other young men at the same stage of engineering development, but have also had the benefit of consulting with men of increased maturity and knowledge. The training these young engineers received makes them much more valuable employees, and results in benefits not only to individuals but also to companies.

(6) Industry is keenly aware of the gap between the need for and the supply of technical and scientific manpower. D. A. Quarles, Assistant Secretary of Defense for Research and Development, has stated: " The critical shortage of engineers and scientists in America is potentially a greater threat to national security than are any weapons known to be in the arsenal of aggressor nations." Industry, government, and educational groups are all working on the problem, and we know that steps are being taken to improve the situation. In the meanwhile, it is important that the most efficient use of the available engineering manpower be made. Co-operative research is one of the ways by which this can be done.

(7) Intangible, but none the less important benefits have been the close friendships that have developed, particularly in connexion with the various field test programmes. In these programmes men worked together, frequently under adverse conditions, for considerable periods of time, but they also had fun together. The fame of the British " Desert Rats " is world-wide. The fame of the CRC " Desert Rats " may not have reached England, but this informal organization is well known among automotive and petroleum engineers in the U.S.A. Organized by a group in the early 1940s who were co-operating in tests of army equipment in the Arizona–California desert, where " pants seat " temperatures ran as high as 135° F, the membership has been augmented by those participating in each succeeding series of tests of military equipment. The *esprit de corps* developed has been so outstanding that the dinner held in Detroit each January is a highlight looked forward to by men who have risen to positions of importance in their own companies since their work in the desert, as well as novice engineers.

(8) From the earliest days of the CFR, the interest of the British in these mutual problems has been evident. Early in 1930 an invitation was extended to a British group in the then Institution of Petroleum Technologists to purchase the equipment and join with the CFR Detonation Subcommittee in some of the knock-rating programmes. The invitation was accepted, and a year later, three men from England attended the Detonation Symposium at the 1931 Annual Meeting, which was reported as follows: " The Detonation Subcommittee of the Cooperative Fuel Research Steering Committee occupied a premier position in the Annual Meeting Programme, not only as sponsor for the most spectacular and best attended session, but as host to Messrs R. Stansfield, C. H. Barton, and C. H. Sprake, co-authors of a contribution to the Detonation Symposium and representatives of the British co-operating committee of the Institution of Petroleum Technologists." Messrs Stansfield and Sprake also participated in the 1934 Uniontown road tests. H. J. Eatwell took part in the July 1949 Road Test Conference, held with the purpose of minimizing personnel and technique errors in future road rating exchange programmes.

R. Stansfield presented a paper on the Sunbury engine at the CLR Symposium on Laboratory Oil Test Engines held in November 1949. As a result

of this Symposium, and subsequent investigations of requirements, it became apparent that none of the available engines would satisfy all the needs of industry. When work was initiated on the development of the new CLR oil test engine, through the co-operation of the members of the Institute of Petroleum, British opinion was secured and correlated with U.S. requirements in designing the engine.

At the present time a considerable amount of information is being exchanged, both formally and informally, between the CRC groups in the U.S.A. and various groups in England. Nothing but good can come from an expanded interchange of data. Anything the CRC and the Institute can do to encourage this will result in increased benefits to all.

WHAT OF THE FUTURE?

Looking to the future, there is an ever-expanding field of research in which the CRC must play its part. The future of CRC is intimately tied to the futures of the automotive and petroleum industries. As these industries advance, so must the CRC.

In the motor fuel field the automobile has evolved from a novelty to an integral part of the way of life. The reciprocating engine has developed from slow, massive power plants to the small, high-speed, high-powered engines of today, but the problems have not all been solved. There are many important jobs to complete and other jobs that can be visualized, and which have yet to begin. The problem of combustion-chamber deposits and surface ignition as it is affected by the fuel, the lubricant, and the engine design is an example of a job yet to be completed. The lack of understanding and standardized research tools are handicapping the industries in their efforts to reach solutions to the problems. The pollution of air by the exhaust from factories, homes, and automobiles has become increasingly critical in certain sections of the U.S.A. and the U.K. The role of the automobile is important, although its exact significance is not yet known. The determination of the composition of the exhaust gases coming from engines is extremely important now, and as the automotive population increases, so will the importance of the problem.

In the aviation field, the reciprocating engine has been dramatically replaced by the gas turbine as the propulsive force in modern aircraft. The work of the CRC in the aviation fuel field is now entirely devoted to the subject of gas turbines and their fuels. The aviation engine industry is developing more powerful engines to make aircraft fly higher, faster, and longer. These new flight engines mean the fuels must withstand different conditions, and new criteria for fuel suitability must be developed. The mutual adaptation of fuels and engines is an ever changing thing with ever changing problems. In the more distant future, as industrial interest and activity in other systems of propulsion develops, CRC work in these fields will be necessary.

The rapidly increasing use of the diesel engine for transport use both by motor trucks and the railroads, as well as in off-highway operations, indicates that even more attention must be paid to this very important phase of CRC work.

In the field of lubricant research there are tremendous potentialities for the future. The use of lubricants solely for the purpose of decreasing the coefficient of friction between moving parts is fast disappearing. The lubricant is being called upon to serve in a number of other ways and to assume its role as a firm partner in the engine–fuel–lubricant field. Wear, deposits, and load-carrying capacity are but a few of the subjects on which information and data are needed.

Originally, the petroleum industry broke down the crude petroleum to form fuels and lubricants. In the future, fuels and lubricants which will be required to work well with the new-design engines will be built up from basic materials. To accomplish this, more fundamental information on the mechanism or mechanisms of combustion and lubrication will be needed.

The past achievements of co-operative research and of the CRC have been many and great, but the opportunities for the future are more numerous and even greater.

The greatest benefit of co-operation is, and will continue to be, co-operation itself—the friendships, the understanding, and the respect created among people and industries all working for the common good.

CURRENT PROGRAMME OF THE CO-ORDINATING RESEARCH COUNCIL *

By T. B. RENDEL † and W. G. AINSLEY ‡

INTRODUCTION

THIS report outlines briefly the scope and objective of the various projects now being carried forward under the auspices of the Co-ordinating Research Council, and discusses in some detail the progress of the work on the more important projects. It should be considered supplementary to the paper entitled "The Co-ordinating Research Council," by M. K. McLeod, which discusses the principles underlying the acceptance of the various projects and the method of operation of the Council. The work of the Council is divided into two broad fields, co-operative research on fuels and equipment and co-operative research on lubricants and equipment. A number of projects are obviously of joint concern to both the fuel and the lubricant and the equipment, and arrangements are made by interlocking membership on the appropriate groups to handle this type of project.

At the present time, the Co-ordinating Research Council is working on forty-one individual projects. This includes a number of CRC groups which make valuable contributions to the overall CRC programme by acting in a supervisory or advisory capacity to the military services, or on work conducted by outside research bodies, such as universities or other research institutes, for CRC, under contract. The CRC Annual Report contains a description of all CRC projects, including information on their current status, except those which have a security classification. Copies of the 1955 edition of this report can be made available to those interested.

A discussion of the more interesting and active projects follows. For simplification they are dealt with under two basic sub-headings, projects under the supervision of the Co-ordinating Fuel and Equipment Research Committee, and those under the supervision of the Co-ordinating Lubricant and Equipment Research Committee.

CO-ORDINATING FUEL AND EQUIPMENT RESEARCH COMMITTEE GENERAL

In this category, perhaps one of the more urgent problems requiring some solution is the matter of air pollution due to exhaust gases of internal combustion engines. Recently, in the U.S.A., there has been a wave of public interest on the subject of air pollution, evolved largely by the somewhat unusual meteorological conditions existing in the Los Angeles Basin. The role played by automobile vehicle exhaust gas in air pollution is probably an important one, though its exact significance yet remains to be determined. Its importance is largely due to the concentration in certain areas of enormous numbers of vehicles. In Los Angeles for instance, vehicles number 2 to 3 million, and it has been calculated by some authorities that the total unburned hydrocarbons from the exhaust gas of automobiles in this area projected into the atmosphere on any one given day is 1100 tons approx. It obviously becomes important, therefore, to know the nature of the exhaust gases put out by different classes of engines operating under different types of conditions, maintenance, and fuels, so that those who carry out research on the effects of air pollution and its cure can know what they must work on. Such an investigation is quite normal for the CRC organization. The work can be carried out in the laboratories of the individual members of the working groups, the result discussed at meetings, and common and uniform research techniques worked out which can then be used by other research workers for investigating various solutions to the problem.

A project of this nature was started by CRC in May 1954. Three panels have been organized, one to develop techniques for sampling and analysis of exhaust gases, a second to investigate such variables as engine design, fuel composition, engine maintenance, and operating conditions, and a third to survey the available literature for information which would be of assistance to the first two panels. This last was important, as an enormous amount of research work had been started in the past few years on this subject, and a number of promising techniques were in evidence.

The first year's work has resulted in the development of satisfactory techniques for evaluating the composition of exhaust gas, and a great deal of preliminary work on the effect of variables has been started. The Literature Survey Panel has done a magnificent job in collecting a vast amount of information and reports.

The CFR Committee is also co-operating with the military services on two other general projects, one dealing with the storage stability of fuels, and the other with the instantaneous measurement of combustion temperatures. Both are long-range, basic research

* MS received 27 May 1955.

† Chairman, Co-ordinating Fuel and Equipment Research Committee.

‡ Chairman, Co-ordinating Lubricant and Equipment Research Committee.

projects financed with industry and government funds and provide a very fertile field for collaboration between the military services' research organizations and industry.

In the field of instantaneous measurement of combustion temperatures, two techniques are being studied, one a sound velocity technique developed by the Massachusetts Institute of Technology, the other an iodine absorption technique developed by the University of Wisconsin. Apparatus to study these techniques has been built, and the preliminary operations to check and calibrate the apparatus have been run. Temperature measurements made to date indicate the techniques will be usable.

CO-ORDINATING FUEL AND EQUIPMENT RESEARCH COMMITTEE AVIATION FUELS DIVISION

The work of the Aviation Fuels Division is now entirely concerned with gas turbines and their fuels, but because of the increasing interest in gas turbines for commercial transport aircraft, each programme has been re-evaluated to ensure that consideration is given to the inclusion of fuels that might be proposed for such use. Broadly speaking, there are two main sets of projects, one dealing with fuel systems and the handling of fuel within the modern high-speed aircraft, and the other dealing with the combustion of the fuel in the gas turbine.

In the first group, two interesting programmes have recently been completed. The first covers the investigation of the volatility characteristics of gas turbine fuels in modern fuel systems at very high altitudes and temperatures. The test results indicated, as expected, that the current JP-4 type fuels are unsatisfactory for aircraft use if heated, by aerodynamic heating or otherwise, to temperatures much above 200° F. For example, JP-4 fuel, when heated to approximately 450° F at very high altitudes will exert a vapour pressure inside a fuel tank of 200 p.s.i.a. By contrast, a heavier fuel, such as No. 2 furnace oil, when subjected to the same conditions will exert a vapour pressure inside a fuel tank of only 18 p.s.i.a. To assist the aircraft fuel system designer, a very comprehensive report has recently been issued (" Volatility Characteristics of Aircraft Fuels at Elevated Temperatures ") which contains much data on fuel volatility and vapour pressure at high temperatures, and presents a relatively simple method for predicting tank pressures resulting from hot fuel.

Considerable work has also been done on the low-temperature performance of gas turbine fuels during the past few years, particularly in regard to their pumpability and filterability. The conclusions from this work may be briefly stated as follows :

(1) Filter clogging by wax crystals and solid contaminants can be controlled by selecting fuels of sufficiently low freezing point and sufficient oxidation stability, and by handling procedures including adequate filtration to prevent solid materials from entering with the fuel.

(2) Fuel selection cannot eliminate filter icing nor can handling procedures prior to fuelling the aircraft. Variation of the water solubility of fuels with changes in temperature can cause unexpected results.

(3) Because of the marked influence of design factors, laboratory data do not provide a reliable basis for the prediction of the low temperature performance of fuel filters and engine controls of an aircraft. Special study of any given design may be necessary to ensure satisfactory low-temperature performance.

In the combustion projects carried out by the Aviation Fuels Division, studies have been made on carbon deposition in full-scale and laboratory type burners, and on the fundamental combustion properties of fuels and their effects on burner performance. Two co-operative programmes on carbon deposition have been completed, and a proposal for a third co-operative programme has been prepared. This last programme has been formulated with the objective of : (*a*) refining current test techniques, and (*b*) identification and evaluation of fuel properties governing deposits and exhaust smoke and flame radiation.

A considerable amount of test work has been completed on fundamental combustion properties of fuels, and a report of some interest has been prepared. Using pure hydrocarbons, a qualitative relation between flame velocity and " combustion efficiency " is described. However, no additional programme is proposed at this time on this latter phase of the work.

CO-ORDINATING FUEL AND EQUIPMENT RESEARCH COMMITTEE DIESEL FUELS DIVISION

Recently, at the suggestion of a number of engine manufacturers, a small group has given serious consideration to the significance, in terms of full-scale engine performance, of current laboratory techniques for the determination of diesel fuel ignition quality. A study has been made of the large amount of work done in various individual laboratories on fuels of varying ignition quality and the effect of fuel ignition quality on full-scale engine performance, particularly with relation to starting, warm-up, and operation under variations in speed and load.

Related to this, some fundamental work has been undertaken by the U.S. Bureau of Mines on ignition delay in a constant-volume bomb. The study was sponsored by CRC and guided by an advisory group from the Diesel Fuels Division. The constant-volume bomb is a reaction chamber which can be charged with air to a given pressure and maintained at a constant temperature. A measured quality of fuel can be injected into the quiescent atmosphere of the bomb in a single injection, and the subsequent pressure–time history of the reacting air–fuel mixture can be re-

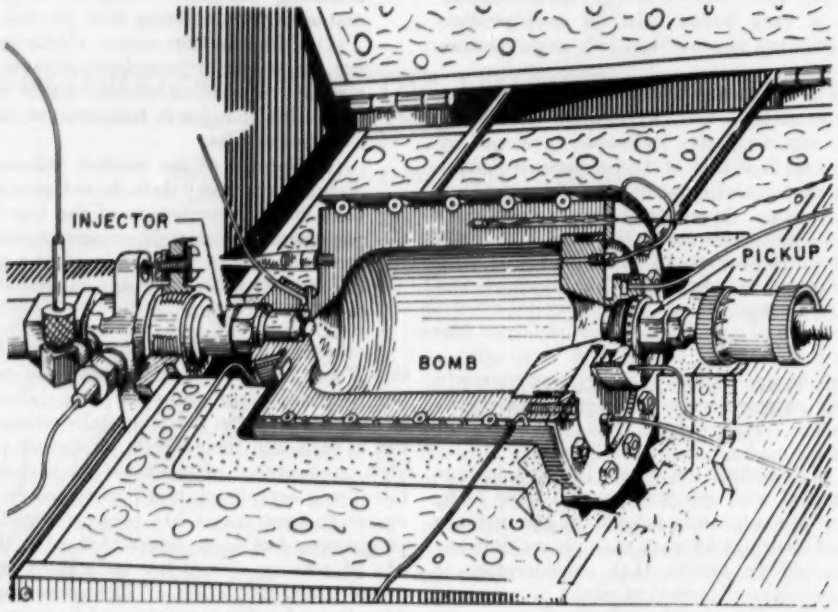


FIG 1
BOMB, INJECTOR, AND PRESSURE PICK-UP

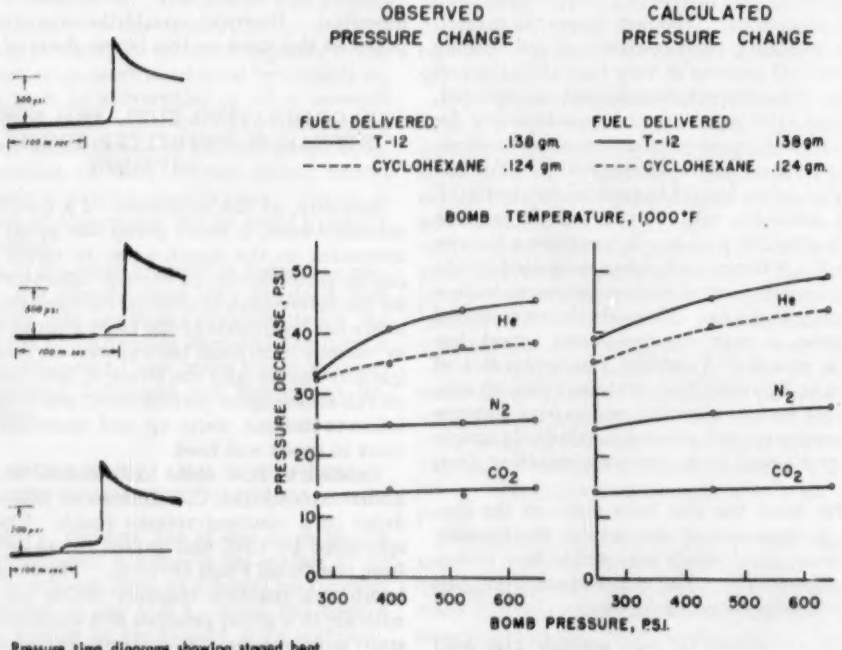


FIG 2

corded, using a suitable type of cathode-ray oscillograph. The CRC Committee publicized this work at the American Petroleum Institute meeting in May 1955, in a paper entitled "Auto Ignition of Fuels in the Constant-volume Bomb, Effects of Operating Variables and Fuel Structure," by Messrs Hurn, Elliott, and Trimble. Fig 1 of this paper shows the general lay-out of the bomb apparatus, and Fig 2 a set of typical data. Since cetane number as measured in an engine is generally recognized as a measure of the ignition characteristics of diesel fuel, it is of interest to examine the relationship between this cetane number

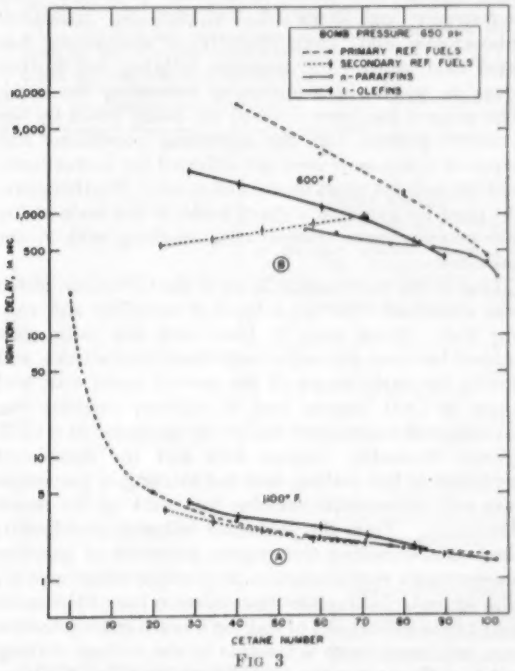


FIG 3

CORRELATION OF BOMB IGNITION DELAY WITH ENGINE CETANE NUMBER

and the ignition delay determined in the constant-volume bomb. This relationship for primary and secondary diesel reference fuels and for *n*-paraffins and 1-olefins is shown in Fig 3. When cetane number is correlated with ignition delay in the bomb at 1100° F, it may be observed that ignition delay always decreases as cetane number increases. The relationship is not constant, but depends on the structure of the fuel. At 600° F, the effects of the fuel structure are much more pronounced. In addition, studies of heat release in the early ignition reactions and a study of the identification of intermediate products, which can be done by means of a sampling technique adapted to the bomb, are expected to yield much valuable information.

Compared with the above as an example of the wide range of research covered by the CRC programmes, there is in progress a very practical field test programme on railway-type diesel engines in actual service. Some years ago, it was foreseen that the type of fuel oil available to the railways might change in nature from the straight-run, fairly high cetane number fuel on which the engines had been developed, and all the initial service experience obtained, to a catalytic-cracked gas oil of lower front-end volatility, somewhat lower cetane number, and higher sulphur content. Accordingly, a series of tests was organized on eight different railways involving three different types of engine and eight different fuel suppliers. The tests were designed to study the effect of the use of high sulphur, low cetane number, high end point diesel fuel, when run against normal type high cetane number straight-run control fuels. Each test was continued over a year's operation on a given railway, in heavy duty freight service, in normal passenger car service, or in switching service. Thus, a very comprehensive set of data was obtained on a comparative basis on two types of fuels. Two series of tests remain to be completed and the data analysed. It is expected that a final report will be forthcoming in the autumn covering all the tests and including some additional work done on smaller full-scale automobile type diesel and some detailed analytical work carried out by the U.S. Bureau of Mines. Pending the completion of all tests, final conclusions are not justified. It is permissible to say at this time, however, that considering only the sulphur content, cetane number, and end point as physical properties of the test fuels, it was possible to operate the locomotive diesel engines under study without sacrificing locomotive availability. However, increased engine maintenance and more frequent overhaul of power assemblies may be necessary.

An improved smoke meter is the goal of another group of the Diesel Fuels Division. The present meters fail to correlate with the density of visible exhaust smoke, and several new types of meters are being tested. Considerable success has been obtained using the filtering-type continuous-recording gas sampler for measuring the relative density of smoke in the visible and invisible range.

The subject of deposit-forming characteristics of diesel fuels and engines has recently received a great deal of attention by a small group appointed to accumulate and review all readily-available information, both published and unpublished, relating to this subject. A very comprehensive report will be issued shortly dealing with influence on the formation of deposits of such factors as engine design, engine operating conditions, and fuel characteristics. The deposits considered are those encountered as the result of the combustion of the fuel, and do not primarily concern deposits due to fuel instability prior to injection. In this same general programme a small advisory group has been assisting the U.S. Navy Bureau of Ships in programming some full-scale submarine engine tests to evaluate the effects of fuels from foreign sources which might have a relatively high sulphur content and which might have to be used in an emergency under operating conditions, such as snorkelling for long periods of time.

CO-ORDINATING FUEL AND EQUIPMENT RESEARCH COMMITTEE MOTOR FUELS DIVISION

During the past few years, the various laboratories active in CFR and CLR affairs have individually been responsible for some extremely interesting work on the subject of combustion chamber deposits in motor car engines. This has led to the initiation of a new programme on the study of surface ignition. In this field a standardization of terminology, a review of surface ignition instrumentation, and a study of surface ignition reference fuels are considered the projects most worthy of co-operative study.

Standardization of terminology should go a long way to clearing up misunderstandings and correlating an immense amount of work which is being carried out in the various laboratories of the petroleum and automobile industries. The term " pre-ignition " has been used in a generic manner for years to describe a number of types of abnormal combustion, but is now being restricted to its specific meaning. The term " surface ignition " is to be used as a generic term for these types of abnormal combustion. Definitions for the basic types of combustion, including normal combustion, and the various manifestations of abnormal combustion have been prepared and are shown in Fig 4.

The review of surface ignition instrumentation is proceeding rapidly, and a number of different types of instruments are being studied. The two objectives of the panel are : (1) to see if different kinds of instrumentation showed the same type of occurrences and surface ignition phenomena, and (2) to obtain ratings on a group of fuels as to their relative resistance to surface ignition.

For many years, the Motor Fuels Division has been concerned with the octane number requirements of passenger cars and commercial vehicles, as they are operated by the public according to the designers' specifications. This type of work continues to be an important feature of the CRC's programme. In 1950, a four-year programme was established with the following objectives :

(1) To supply statistical information on octane number requirements of the post-war car population.

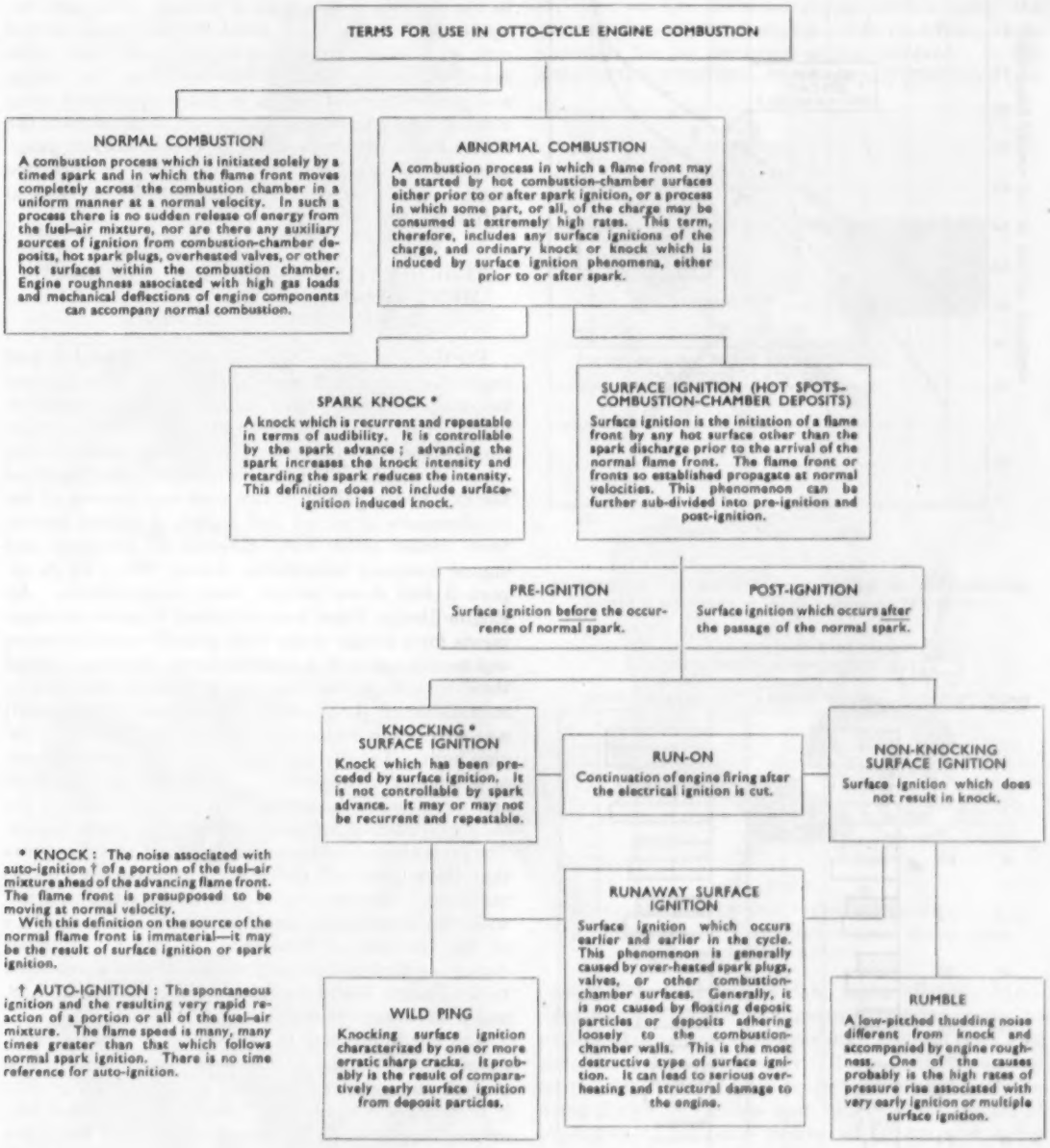
(2) To study the octane number requirements of selected makes and models, having new-design engines or transmissions (new design cars).

In 1951, the first year of the programme, a statistical survey of 1946–51 models was conducted. This survey gave results nearly identical to those of the 1949 statistical survey. Data on three makes having new-design engines and transmissions were also obtained. In 1952 and 1953 the work was devoted entirely to the study of makes having new-design engines and transmissions. The 1954 programme included a statistical survey of 1950–54 model cars in addition to studies of the requirements of nine 1954 makes having new-design engines and transmissions. Fig 5 sums up the results of the statistical surveys. Fig 6 sums up the results of 1954 cars. In these latter tests, it is noteworthy that the percentages of cars reported to be spark knock or surface ignition limited on the primary reference fuels were 96 per cent spark knock limited and 4 per cent surface ignition limited.

As might well be expected from a study of octane number requirements and the octane numbers of gasolines currently marketed in the U.S.A., the subject of an extension of the octane scale is very much to the fore. Some two years ago, some proposals were tentatively put forward for trial by interested laboratories and, more recently, a symposium has been held under CFR auspices to bring out further ideas as to the best means of extending the scale. The subject has been covered for many years by the aviation groups, but the operating conditions and types of equipment used are different for motor fuels, and the subject must be studied anew. Furthermore, the need for avoiding a sharp break in the scale at the 100 point is more critical when working with motor gasolines.

One of the very early studies of the CFR Committee was concerned with the subject of volatility and vapour lock. From time to time over the years, this subject has been studied in individual laboratories, and during the early stages of the second world war, and again in 1950, vapour lock in military vehicles was investigated thoroughly under the guidance of a CFR group. Recently, vapour lock and the associated problems of hot stalling and hot starting in passenger cars and commercial vehicles has come up for much discussion. From the petroleum industry standpoint, the need for raising the vapour pressures of gasoline has become a very attractive proposition commercially. The advent of automatic transmission has at the same time made the subject of stalling a much more sensitive one, and much more noticeable to the average driving public. Consequently, in 1953 a comprehensive survey of the difficulties being experienced in service throughout the U.S.A. was made, covering a total of 140,000 cars approx. Results of this survey were somewhat different from those which had been expected, and because there was some question as to the uniformity of the techniques used in conducting the survey, a second trouble spot survey was conducted in 1954 to determine if the preliminary indications were confirmed. In a separate programme a new technique was developed for evaluating the vapour-locking characteristics of individual cars which permits the study of vapour lock, hot stalling, and hot starting during a single test schedule. At the present time, the results of the 1954 survey have not been fully analysed, and it is therefore impossible to say whether the 1953 results have been confirmed or not. The analysis is proceeding as rapidly as possible, and it is hoped that a report combining the results of the two surveys will be available for publication some time in the autumn.

Since 1951, a group has been actively assisting the


TERMS FOR USE IN OTTO-CYCLE ENGINE COMBUSTION
NORMAL COMBUSTION
A combustion process which is initiated solely by a timed spark and in which the flame front moves completely across the combustion chamber in a uniform manner at a normal velocity. In such a process there is no sudden release of energy from the fuel–air mixture, nor are there any auxiliary sources of ignition from combustion-chamber deposits, hot spark plugs, overheated valves, or other hot surfaces within the combustion chamber. Engine roughness associated with high gas loads and mechanical deflections of engine components can accompany normal combustion.
ABNORMAL COMBUSTION
A combustion process in which a flame front may be started by hot combustion-chamber surfaces either prior to or after spark ignition, or a process in which some part, or all, of the charge may be consumed at extremely high rates. This term, therefore, includes any surface ignitions of the charge, and ordinary knock or knock which is induced by surface ignition phenomena, either prior to or after spark.
SPARK KNOCK *
A knock which is recurrent and repeatable in terms of audibility. It is controllable by the spark advance; advancing the spark increases the knock intensity and retarding the spark reduces the intensity. This definition does not include surface-ignition induced knock.
SURFACE IGNITION (HOT SPOTS–COMBUSTION-CHAMBER DEPOSITS)
Surface ignition is the initiation of a flame front by any hot surface other than the spark discharge prior to the arrival of the normal flame front. The flame front or fronts so established propagate at normal velocities. This phenomenon can be further sub-divided into pre-ignition and post-ignition.
PRE-IGNITION
Surface ignition before the occurrence of normal spark.
POST-IGNITION
Surface ignition which occurs after the passage of the normal spark.
KNOCKING * SURFACE IGNITION
Knock which has been preceded by surface ignition. It is not controllable by spark advance. It may or may not be recurrent and repeatable.
RUN-ON
Continuation of engine firing after the electrical ignition is cut.
NON-KNOCKING SURFACE IGNITION
Surface ignition which does not result in knock.
RUNAWAY SURFACE IGNITION
Surface ignition which occurs earlier and earlier in the cycle. This phenomenon is generally caused by over-heated spark plugs, valves, or other combustion-chamber surfaces. Generally, it is not caused by floating deposit particles or deposits adhering loosely to the combustion-chamber walls. This is the most destructive type of surface ignition. It can lead to serious overheating and structural damage to the engine.
WILD PING
Knocking surface ignition characterized by one or more erratic sharp cracks. It probably is the result of comparatively early surface ignition from deposit particles.
RUMBLE
A low-pitched thudding noise different from knock and accompanied by engine roughness. One of the causes probably is the high rates of pressure rise associated with very early ignition or multiple surface ignition.

* KNOCK: The noise associated with auto-ignition † of a portion of the fuel–air mixture ahead of the advancing flame front. The flame front is presupposed to be moving at normal velocity.

With this definition on the source of the normal flame front is immaterial—it may be the result of surface ignition or spark ignition.

† AUTO-IGNITION: The spontaneous ignition and the resulting very rapid reaction of a portion or all of the fuel–air mixture. The flame speed is many, many times greater than that which follows normal spark ignition. There is no time reference for auto-ignition.

FIG 4

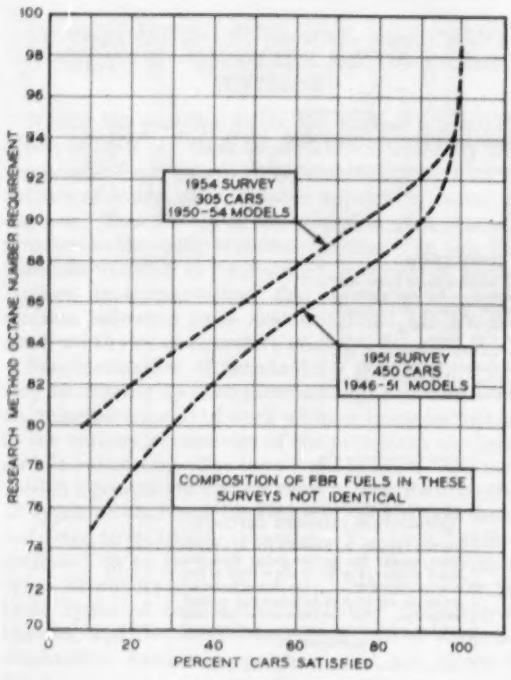


FIG 5

DISTRIBUTION OF MAXIMUM REQUIREMENTS. STATISTICAL SURVEY, FULL-BOILING-RANGE REFERENCE FUELS

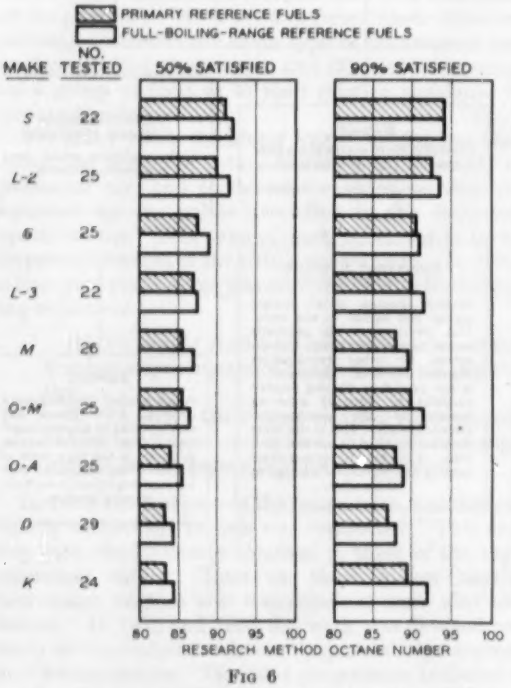


FIG 6

OCTANE NUMBER REQUIREMENT AT 50 AND 90 PER CENT SATISFIED POINTS, 1954 MODELS

office of the Chief of Ordnance of the U.S. Army in the evaluation of vapour lock, octane requirements, and cold-starting characteristics of current and future military equipment, and in training ordnance personnel in the conduct of this type of testing. Extensive co-operative tests on these problems have been carried out at various army proving grounds, and were found extremely beneficial in improving the design and performance of certain military equipment using combat-type gasolines. The record of the work of the Motor Fuels Division cannot be closed without reference to the excellent and important co-operative work between industry and the military services in fitting fuels to military vehicles.

CO-ORDINATING LUBRICANT AND EQUIPMENT RESEARCH COMMITTEE ENGINE LUBRICANTS DIVISION

For the past few years, the need for a special oil test engine has become increasingly urgent. This urgency became vital when the General Motors Corporation notified CRC that after 1956 the supply of Chevrolet engines used for L-4 testing for sludge and bearing corrosion would no longer be available. As a result of the experience gained in two post-war reviews of the requirements of an oil test engine, a special survey team visited about forty different oil company and engine company laboratories during 1952. In its report it laid down certain basic requirements. An Engine Design Panel was authorized to make arrangements for a design study with suitable manufacturers and to come up with a suitable design, keeping in mind these basic requirements. As a result of this work, a manufacturer (Laboratory Equipment Corporation) was selected, a design approved, and a prototype engine built. Twenty-five engines are now in the hands of a number of laboratories for further development and for working out suitable operating techniques for the evaluation of different phases of oil performance. The preliminary results are satisfactory, and it appears that the engine will prove very valuable for oil test purposes. The new engine is to be discussed in detail with the appropriate standardization sub-committee of the Institute of Petroleum on July 1. A paper discussing its development has recently been presented to the Fourth World Petroleum Congress. Figs 7, 8, and 9 show various features of this engine.

Another interesting subject which is being investigated by the Engine Lubricants Division of CLR is a project on engine varnish and sludge. Its objective is to develop "know how" which will permit a laboratory to obtain in laboratory engine tests the types of engine condition, such as deposits, wear, etc., which are encountered in several types of engines in various types of field service. At the present time the group is studying four items: (*a*) the formation of cold-sludge-type engine deposits; (*b*) reproduction of oil ring plugging; (*c*) inlet oil screen plugging; (*d*) formation of typical engine deposits as occur in field tests.

A comprehensive programme is under way to explore

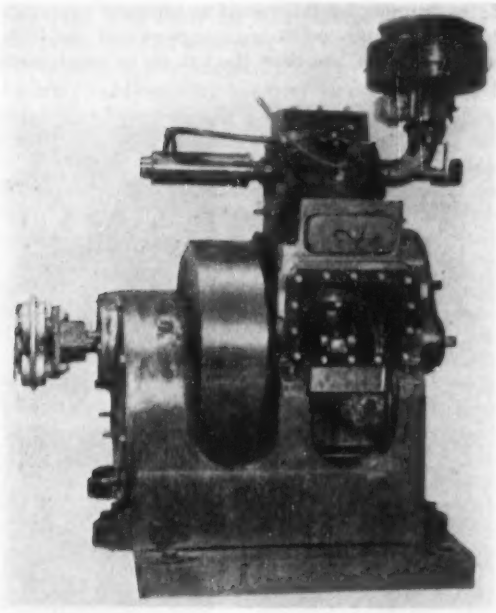


FIG 7
CLR OIL TEST ENGINE, LEFT

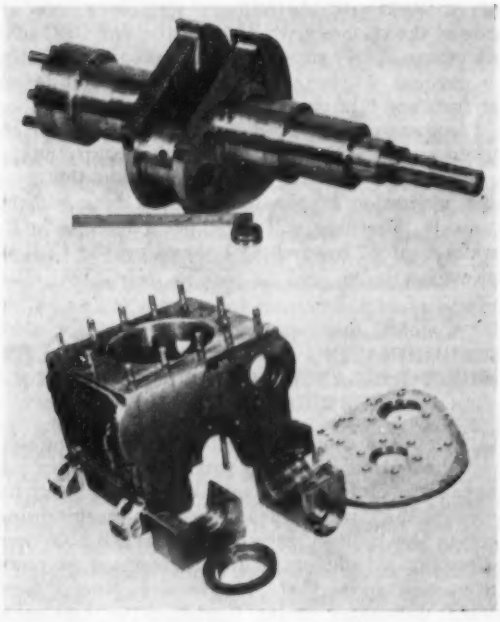


FIG 8
A. CRANKSHAFT
B. CRANKCASE AND MAIN BEARING BLOCKS

the effects of equipment variables and to check reproducibility and repeatability. The tests have been set up on a statistical basis to cover: (*a*) runs employing reference oils on which field service tests are available; (*b*) runs on five different engine models using the general plan of the technique but modifying it as necessary for the particular engine involved. In the latter tests one fuel is used and one pair of oils on which

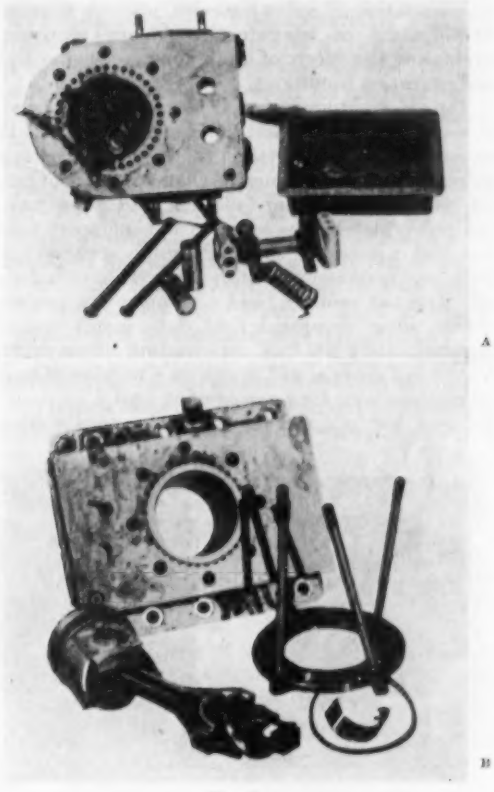


FIG 9
A. CYLINDER HEAD AND VALVE MECHANISM
B. CYLINDER, CYLINDER HOLD-DOWN PLATE, AND PISTON AND ROD ASSEMBLY

considerable field service data are available. Standard data forms have been prepared and distributed to participants as an aid in providing uniform data and simplifying the analysis work. Reproducibility among laboratories with respect to piston varnish and side cover sludge ratings has been improved by the use of photographic reference charts, which are now being made available to all participants. Figs 10 and 11 present examples of these charts. If this rating system proves satisfactory, it will be expanded to include other engine items.

Recently, at the request of the Association of American Railroads, the CLR has agreed to study the subject of lubricating oils for railway diesel engines. The objective of this project, stated broadly, is the deter-

mination of the mutual interdependence of different types of lubricants and different types of railway engines under a variety of operating conditions, recognizing the mutual effect of railway fuels. As a preliminary step, it is intended to conduct a survey of field experience to summarize the available information on the problem. Then, if warranted, it is planned to carry out field service tests to permit the development of field service techniques capable of predicting results representative of railway service, and the concurrent development of laboratory techniques capable of evaluating the effects of lubricating oil, engine design, and operating conditions.

The old nightmare of wear has recently cropped up in a specialized form, and the Engine Lubricants Division of CLR has undertaken to study it. The engine manufacturers have indicated that a problem of excessive wear in cams, cam followers, and gears has developed in higher horsepower output engines now being installed in passenger cars. Preliminary surveys show both engine design and lubricating oil have a definite effect on the problem, and a co-operative project to obtain some organized field data seems desirable. Approximately 300 cars, representing eleven different makes and models, will be run on a number of engine-oil combinations for a period of at least a year. Four different test oils will be used and specially selected

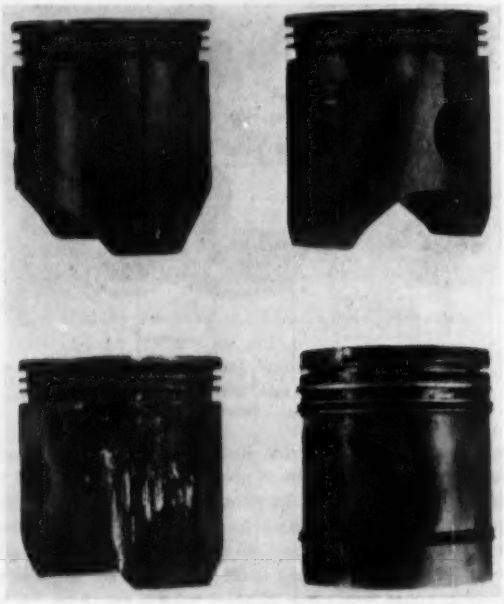


FIG 10
CLR PISTON RATING CHART
Rating 3

lifters installed in various cars prior to the test. The cars will be driven in normal passenger car service in various areas throughout the U.S.A.

As in the case of fuels, an investigation of the engine–lubricant relationship in military equipment, including the air-cooled tank engines and the liaison aircraft engines, has been the subject of much co-op-

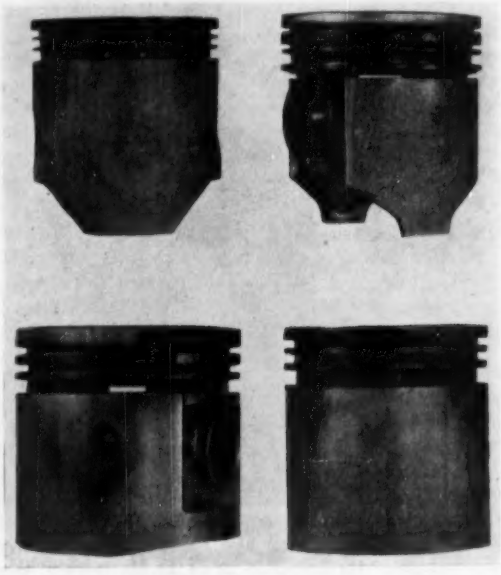


FIG 11
CLR PISTON RATING CHART
Rating 8

erative work with the military services. Tests are made at the various army test centres, and CRC advisory groups closely supervise them and assist in rating the engines by providing special inspection teams. The fuels and lubricants which are being used in these field test programmes are being made available to the various groups of the CLR, such as the group studying engine varnish and sludge, to ensure that the maximum utilization of the field service data is being attained. The data will be of particular use in the development of research techniques on the CLR oil test engine.

CO-ORDINATING LUBRICANT AND EQUIPMENT RESEARCH COMMITTEE VEHICLE LUBRICANTS DIVISION

A number of companies in the petroleum industry has indicated concern with rear axle failures in passenger cars. Information submitted to the group has indicated that, while a few years ago the lubricants meeting the military specification MIL-L-2105 were performing satisfactorily, due to increase in power output and speed there has been a general trend toward difficulties under conditions of high-speed operation. Also, the load-carrying ability of gear lubricants has been taxed by the additional loads being imposed in both commercial and military vehicles.

Plans have been made for comprehensive surveys of these problems, and studies of the reproducibility and severity level of the two techniques in current use for measuring load-carrying capacity in rear axles under conditions of high-speed, and high-torque and low-speed (L-19 and L-20) have been proposed. To ensure that the techniques remain on a uniform level of severity, as a means for screening defective test axles, and to make it possible to convert from one test axle to another of a new design, arrangements have been made for the establishment of a set of calibration oils. As another project, the CRC is assisting the Ordnance Corps in inspections and evaluation of the performance of gear lubricants in military vehicles.

The subject of automatic transmission units and power steering units and their fluids is also being studied by a group in the Vehicle Lubricants Division. A test technique using a commercial transmission unit has been tentatively established. The first work has been done on common reference fluids, including acceptable, unacceptable, and borderline oils, the object being to determine whether this transmission can be used and what modifications are necessary to make it suitable for use as a test apparatus. This work is proceeding smoothly, but of necessity each test is of a fairly long term nature, and no conclusions are available. The programme seems to be a promising one from the point of view of yielding results.

CO-ORDINATING LUBRICANT AND EQUIPMENT RESEARCH COMMITTEE AIRCRAFT LUBRICANTS DIVISION

In the field of aircraft lubricants, a comprehensive study of airframe lubricants and equipment is being carried out by a group at the request of the U.S. Air Force and the U.S. Navy. The purpose of this work is to determine the lubricant requirements of the various mechanisms built into the aircraft so that changes in both the aircraft or accessory design and the lubricant can be made to obtain the best overall effectiveness. Included in this study are the problems of rust prevention, high-temperature operation, and fret corrosion, as well as instrument bearing and plain bearing problems. One of the most important factors in this study is service test data, which have been very difficult to obtain in the past. Extensive service test programmes on a number of these problems are under way, and it is expected that adequate information will be available as the individual tests progress. Service information on the wheel bearing corrosion problem, on the incidence of fretting corrosion, and on anti-friction bearings for electronic equipment has been made available to the appropriate laboratory groups. In the laboratory groups test programmes to develop techniques covering high-temperature testing of greases, fretting corrosion, rust preventive properties of grease, plain bearings, and screw thread and gear mechanisms have been organized. In the rust preventive field the group has drafted a tentative static technique for the prediction of rust preventive properties of greases and is now investigating dynamic techniques.

Final conclusions on the value of these techniques are awaiting the results of field tests, but again it should be borne in mind that all these tests, both service and laboratory, necessarily take considerable time to carry out, since long life is the basic factor which has to be measured. Experience has shown that it is impossible to shorten up laboratory time appreciably and still maintain adequate correlation with service data.

An advisory group has been assisting the U.S. Air Force to develop a bearing test rig for studying problems connected with the development of main thrust bearings of gas turbines.

Finally, mention must also be made of a very extensive programme which was initiated some years ago to study the use of compounded lubricating oil in reciprocating aircraft engines. Flight service tests were conducted by the Air Force on a series of compounded oils in B-36 and B-50 aircraft, and a full-scale multi-cylinder engine test programme designed to evaluate overall engine performance, was carried out by the military services. Laboratory bench techniques which were available to various industrial research laboratories were run on these oils and an endeavour was made to establish a series of techniques covering such items as sparking plug fouling and pre-ignition tendencies, which would correlate with the field service data. The field service data did not indicate any serious differences between the various oils tested and the basic uncompounded reference oil. Even though the test periods extended from 400 to more than 800 hr in duration, it was not possible to run the full-scale trials long enough to establish fully any possible differences which might have occurred. In view of the lack of interest in the piston engine and its lubricating oil in the future, this project was concluded.

CONCLUSIONS

Because of the continuing problem of ensuring the most economical usage of CRC manpower and facilities, particularly at the present time when research manpower is so scarce, the appropriate CRC Committee maintains a very critical review of all CRC projects so that only those projects which are of vital importance to the automobile and petroleum industries or the military services are maintained as CRC activities. Before starting laboratory or field test work, the scope and objective of a project is fully discussed and thoroughly understood by all those involved. After the data are collected, great care is taken to see that they are studied and analysed until it becomes clear that they are sufficient and can be significantly resolved to the satisfaction of all concerned. Finally, care is taken that, with the exception of classified material, all reports are given the widest possible distribution through appropriate channels such as the publications of the Society of Automotive Engineers and the American Petroleum Institute.

WHAT THE CRC MEANS TO THE PETROLEUM INDUSTRY*

By W. J. SWEENEY†

MANY years ago, it was recognized that there existed a need for a forum to study and define the mutual problems of the petroleum industry and the equipment industries which use its products in areas which are not competitive. Today, that forum is established in the CRC and although the petroleum industry spends over $100 million per annum on competitive research, all the CRC activities together cost it less than 1 per cent of that total. It is not difficult to set out one problem in 100 that is of a strictly non-competitive nature but is of public interest. It is in this non-competitive area that the CRC has become very valuable to the petroleum industry. The CRC does not, however, participate in activities leading to product specifications.

Among some of the familiar ways in which the CRC benefits the petroleum industry are the following. First, and perhaps most important, is that the CRC sets up techniques for establishing equipment requirements and develops a common language for expressing the results. Most people in the petroleum industry know the meaning of road octane requirement for a motor car, and the technical men in this field know exactly how it is obtained. It is they who have established a wide variety of equipment tests and methods. Similarly, they have established universally used techniques for evaluating the performance qualities of petroleum products, and product quality technicians know exactly what is meant when reference is made to the octane number of a gasoline, or its vapour locking tendency, or its starting quality. Similarly, in the field of lubricant evaluation, the CRC have published methods and practices which are invaluable to the petroleum industry and which are standard throughout the world. Even countries such as Germany, which have a highly skilled technical economy, used CRC procedures for quality control during the second world war.

There are certain areas where no one oil company, regardless of its size and the extent of its research facilities, could hope to cope with the technical problems faced. In these areas, the CRC co-ordinates activity, such as the determination of military equipment performance requirements for petroleum products, *e.g.* cold starting, vapour lock, and overall volatility demands. The stability of motor and aviation fuel for long time storage, and the influence of storage conditions and the containers used, are problems where CRC has been most helpful. The requirements for arctic grade oils and the broad subject of engine wear were two other problems where the CRC was helpful. By assembling a corps of experts from the automobile and petroleum industries, and working with the military personnel, such problems are effectively studied.

There are other areas where a mass of statistical data—otherwise unobtainable at reasonable cost—are collected and analysed by the CRC for the benefit of all concerned. The performance of various petroleum base stocks, chemical components, processing methods, and effectiveness of additives can be statistically evaluated in this way. CRC technical reports of projects carried out in all of these fields are released to the API and the SAE for publication and general distribution.

During the second world war, the CRC marshalled automobile and petroleum product quality technology into a pool from which the military authorities could draw the best information possible—it is a tremendous compliment to both CRC and its supporting industries that during that time neither trade secrets nor competitive considerations were ever a basis for withholding information—nor was a single confidence ever destroyed. The petroleum industry is highly appreciative of what the CRC accomplished for them during those troubled years.

An offshoot of these activities, which is not generally appreciated, is the training given to the members of the working panels and committees of the CRC, comprised in the main of the more capable younger men in both industries. Today, a great deal of emphasis is placed on the training of young men, and old timers like to think they are the ones who do the training. In a sense, they are—but the most effective training frequently is in simply directing young men along avenues where they can meet with other men of high calibre and benefit from that association. This is often a matter of particular importance to the petroleum industry. The technical manpower in the petroleum industry is essentially a family of engineers and scientists. Today, it is a rare find when one acquires a chemist or a chemical engineer who knows and likes mechanical engineering. The CRC has been very helpful in providing an opportunity whereby chemists and chemical engineers can become familiar with things mechanical, and have contact with other young engineers having different interests. The reverse is also true that mechanical engineers tend to avoid chemistry—so they benefit also in this communion of interests. It is perhaps in this general training area where the CRC makes one of its greatest contributions to the petroleum industry. It provides a common meeting place where the best young brains of the automobile industry and from various units of the petroleum industry—and here and there a university, or research institute, or Govern-

* MS received 29 June 1955.

† Esso Research and Engineering Co. Ltd.

ment agency man—can all exchange ideas and experiences for the common good.

The Esso Organization has frequently been referred to as a company run by committees, and whose executives spend all their time in committee meetings. The same thing has been said of other companies in the petroleum industry. If this is true—and to a certain extent it is true—then CRC is a place where men get fine training in committee functions for their future in industry. To learn to express one's convictions in meetings; to weigh all sides of a problem being discussed; and to arrive at the best decision possible from the available facts presented and still fairly protect his own company's interests—is indeed a valuable proving ground for any company to have. The CRC provides just that kind of experience.

What makes this training doubly valuable is that it can be carried out in an atmosphere where competitive pressures exist but are subordinated, and where pure logic and research data are the only combat weapons. The CRC and its committees function in a competitive atmosphere on non-competitive problems.

Over the past fifteen or more years, the CRC has had some difficult times, along with its successes—but today CRC is better and stronger than ever and a potent source of good for the petroleum industry, and a most valuable training ground for its most valuable asset—the young technical men.

WHAT THE CRC MEANS TO THE AUTOMOTIVE INDUSTRY*

By E. S. MACPHERSON†

THE first two decades of the history of the automotive industry in the U.S.A. saw little, if any, recognition of the fuel and lubricant problem by automotive engineers. During this period the petroleum industry showed no more serious technical interest in the problems of the automobile. Slowly, and yet surely, there has developed a mutual appreciation of the needs of the consumer and of the requirements faced by both industries in the drive to satisfy these needs. The Co-ordinating Research Council has become a vital organ for communication in the technical development of the automotive and petroleum industries. The growth of this co-operative activity, without trespass into the competitive areas of these two highly competitive industries, testifies to the good judgment of the founders as well as that of the continuing participants.

BACKGROUND

The automobile was a novelty when introduced, and "automobiling" as a sport was limited to a relatively few wealthy men. The vision of men like Henry Ford and Ransom E. Olds led them to see the automobile as more than a plaything. To these men the automobile, as a means for fast and reliable transportation, meant that utility and low cost were essential for the widespread use which was to result in an important extension of man's ability to travel, communicate, and to produce.

Mass production and distribution made it possible for millions of people to own an automobile. This in turn revealed the many problems inherent in the utilitarian aspect of automobile use which would not have been significant in a sport. Automotive engineering as a specialized profession grew from the need to solve these problems.

At the time of introduction of the automobile, gasoline was a waste product of an industry whose first interest was the refinement of kerosine for lamp oil. The manufacture of lubricants was largely by proprietary techniques and formulæ based on empirical data rather than a truly rational technology. The increasing use of automobiles changed the demand for refinery products, and it is interesting to note that this was concurrent with the widespread development of electric power and electric lighting. To understand and to meet these demands it became necessary for the petroleum industry to establish automotive research laboratories.

These developments occurred in a period of great technological growth. In contrast to the slower, more gradual development of the past, there has been in the first half of the twentieth century, an explosive rate of technical development. It was no longer possible to do slow and careful individual research in a relatively static environment. Constant and rapid change required an almost immediate knowledge of new market requirements, and ultimately a foreknowledge of planned change before its occurrence. This is not unique to the petroleum and automotive industries, however, the need for co-operative research between these industries was emphasized by the intimate technical relationship of fuels and engines and by the growing magnitude of the market for their products.

PRINCIPLES

The principles of operation of CRC developed from the recognition of the nature of technical need. The natural competitive pressure to develop new and different solutions to each problem made it essential that specific solutions be excluded from the co-oper-

* MS received 14 June 1955.

† Vice-President, Engineering, Ford Motor Co.

ative area. The work of CRC was, therefore, limited to the investigation of the effect of equipment design, fuel and lubricant characteristics, and of operating conditions as independent variables and in combination with each other.

The specific problems of a single producer are usually related to some individual peculiarities of design or technique. It is only when a problem involves industry-wide interest and effort that co-operative research is justified. Although it has not been expressed formally as a principle of operation, it is, nevertheless, true that co-operative research usually consists of a pooling of efforts, with common guidance, which otherwise would be expended individually. The one exception is research in non-commercial problems at the request of a government agency.

The result of the application of these principles is that the projects pursued have had the active support of the individual members of both industries, that the personnel engaged in each project have been the best qualified from each of the individual companies, and that the information obtained has been put into practice as expeditiously as possible.

PROCEDURE

The procedure for each project varies with the nature of the problem, and the present paper does not deal with the formal organization. In general, the history of a problem proceeds as follows: The problem is introduced by one of the advisory committees as a representative of the interested industry. The Assignment Committee considers the proposal to determine that it satisfies the CRC principles of operation and upon approval assigns it to the CFR or CLR Committee. The project is assigned in turn to one of the divisions of the principal committees, and to the appropriate group if one exists, or to a newly created group if required. Alternatively, a group or division may initiate a project within its scope with the approval of the Assignment Committee.

The first step in the attack is a clear definition of the problem and the scope of Group to which it is assigned. This may require a field survey to acquire the data needed for definition or alternatively a review of available background data. Prior to the co-operative effort, the individual researchers probably used a variety of technique, instrumentation, and operating conditions. Nevertheless, an exchange of information and an analysis of data and methods quickly reveals the direction to be taken.

In many cases, the research tools are available and in common use; however, if there is need at this point, instrumentation, test apparatus, and techniques are agreed upon or developed especially for a specific case. The use of an approved research procedure develops data which are easily correlated and analysed, and insures a consistency of knowledge which leads to a common understanding.

There is often a need for consistent test material. This can be in the form of a precisely designed reference fuel, in the form of lubricants of graduated characteristics, or in the form of specially defined or controllable mechanical equipment. This material is made available or procured for distribution as required to insure uniformity of results.

As the use of the techniques and material progresses, in the individual laboratories, the data developed are correlated by exchange panels. The exchange of data not only provides the researcher with a greater total of information than each would develop alone, but also makes possible a planned programme to cover more completely a wide range of tests. This makes it possible to solve problems requiring a statistical analysis of mass data which would ordinarily be beyond the ability of a single laboratory.

Finally, a comprehensive report is written for the reference of anyone who wishes to use it, and frequently papers are presented to the appropriate technical societies to familiarize their members with the completed project.

SOME TYPICAL PROBLEMS

After the end of the second world war, automobile production was resumed. The first cars built were substantially identical with the last of the pre-war models. Fuel had been produced throughout the war for civilian use, since military requirements had led to an alteration of refinery operation. During the period of the war, all research effort had been on military projects, and civilian vehicle research had been suspended. There quickly developed evidence that this hiatus of co-operative research had permitted some problems to grow to serious proportions. Among these was vapour-lock—and in 1946 teams of automotive and petroleum technicians were assigned to the problem under the guidance of a CRC group. Technicians were improved and reliable data were quickly developed; however, no less important was the fact that new and younger personnel were able to become familiar with the problem. Vapour-lock was brought under control and reduced to a reasonable minimum almost immediately.

Again, the increasing use of automatic transmissions focused attention on the problem of combustion chamber deposits. These deposits had previously been responsible for no more than a gradual deterioration of performance in a car with a standard transmission, and, the loss of engine performance seriously interfered with the proper control actuation of automatic transmission cars. Through the efforts of CRC a symposium was held for a complete exposition of the problem. From this grew techniques which led to the development by individual companies of fuel additives for deposit control, combustion chambers designed to be deposit-inhibiting, and sparking plugs which are not deposit-sensitive.

Finally, the continuing survey of octane requirement in the field has provided a better understanding

of the variables, and of the effect of design change in customer service. The improved correlation of laboratory and road ratings has permitted accelerated combustion chamber development. When taken together with the data on characteristics and volumes of fuel sold, it is possible for the individual companies to make almost precise choices as to the desired octane requirement of new vehicles. In the past, when less explicit methods were used it was common practice to allow as much as six octane numbers below the prevailing level as a safety factor during vehicle development. Through the use of more precise analysis it is possible to reduce this to two octane numbers or less and to achieve the highest tolerable compression ratio.

These are only a few of the many projects, but they illustrate the important benefit to the automotive industry of co-operative research. There is no possibility that individual research could have provided the same benefits of rapid development and adaptability required by the major changes of the post-war era. As a single example, compression ratios have changed as much in the past five years as they did in the preceding twenty years. It is significant that this was accomplished in an orderly and rational way because of the background of co-operative research.

ADDITIONAL BENEFITS

The development of co-operative research through CRC has meant more to the automotive industry than the solution of specific problems, important as these have been. Active participation in CRC projects has been an unexcelled training ground for young personnel. They benefit from the contact with more experienced men and have the opportunity to learn how to approach their own specific problems. They are reminded that there is reasonable ground for more than one opinion, and that, through voluntary joint effort, agreement can be developed when the same knowledge is shared by all. This makes them more valuable and effective in the laboratories of their own company.

During the second world war, the automotive industry was called upon to develop military vehicles of many new and strange types. Inevitably, problems appeared which were outside the experience of its design groups. Through co-operative research, each industry was able to help the other in the solution of these problems. All the accumulation of knowledge and techniques was also made available to new producers who had no previous experience of their own and often lacked the facilities for adequate research. The two industries are proud of their contribution to the war effort and feel sure it was enhanced by co-operative research.

The essence of civilization is man's ability to communicate, and any extension of that ability is inevitably an extension and refinement of civilization. The development of a common technical language between the petroleum and automotive industries is just such an extension. This common language has led to a better understanding of each other's problems and to a recognition that the best solution for the consumer lies in a compromise between the abilities of the two industries. Certainly, the industries recognize that in the past they both manufactured problems for each other and for the consumer. This may still occur by chance, but the probability is less because of a better understanding. Also, should it occur, a resolution of the problem will be arrived at more quickly because of their common language and because of the bridge of co-operative research.

The preservation of a competitive attitude, concurrent with the development of co-operative research, is a sign of a mature appreciation of the benefits to be derived from each. In a world often confused in its larger affairs, mankind continues to make progress in its everyday affairs. The Co-ordinating Research Council, and the co-operative work supported by both the automotive and petroleum industries, is an exemplar of such progress.

DISCUSSION

C. S. Windebank : In opening the discussion, I propose to use as my theme, the very obvious one of examining whether it would be advantageous for the British petroleum and automobile industries to co-ordinate along the lines of the CRC.

First, what is the purpose? Mr McLeod sums up the purpose of the CRC in the U.S.A. very aptly by saying it is set up to serve the mutual customers of the participating industries well. Do we have the same objective here in the U.K.? I, for one, would say that without a doubt we have. The motor industry in the U.K. is international, in that its products are found in all corners of the world. Correspondingly, the oil industry with its international foundation now has an integrated system of refining and marketing here in the U.K. This, of course, is a post-war innovation. The products of the one industry consume some 25 per cent—a substantial proportion—of the products of the other. But the influence of that 25 per cent is much higher than the bare figure indicates, because the motor spirit requirements determine to a very great extent the refining processes which the oil industry instals in its refineries.

Correspondingly, the quality of the petroleum product which is available, and which will be available, in the market is the basic consideration affecting the design of internal combustion engines, and, in turn, the design and the performance of the motor car. I cannot imagine in these circumstances, that anyone can feel that close liaison between the personnel of the two industries is not essential, and if, as is my own opinion, it is not close enough at this time, then surely our immediate objective is to provide some means of making it closer. Do we want to go through a similar experience to that we had in war time, with 3½ c.c. TEL in motor spirit? The belated co-operative work which stemmed from that experience, set up the beginnings of a liaison (much in the same circumstances as those in which CRC originated) which, unfortunately, has been allowed to elapse since the war.

When people are talking about setting up a new organization, it is always a sound principle to examine existing organizations to see whether one or other of them is not already well equipped to do the job. This is one of the things we should not forget to do. On the petroleum side, we have the Institute of Petroleum, with an existing and operating Research Committee. That, I imagine, bears some correspondence to API in the U.S.A. On the automotive side, we have the Institution of Mechanical Engineers, whose building we are using today. Its Automobile Division, I imagine, corresponds very closely to the SAE. We have also the Motor Industry Research Association. Perhaps a closer interest by each of these bodies in the others' activities is all that is really necessary. Possibly, an annual joint-meeting or a symposium on technical subjects might go a long way towards filling the need, which I feel exists. This should be explored, at least as a start.

It is interesting to note that in the U.S.A. there exist equivalent bodies, and yet it was decided many years ago that something more was needed to supplement their activities—an organization, in fact, which sponsored and directed research work. This is the essence of the CRC's scheme, and the question which I am raising can be expressed by asking: Can liaison between the two industries be truly effective without jointly sponsored research? Co-operative research has its problems and its deficiencies. By its very nature it is slow, and therefore expensive. The oil industry in the U.K. has a natural disinclination towards co-operative work within the industry. The work as organized by CRC needs laboratories, which in the U.K. are all too few in number, and work of that sort calls for a scale of expenditure which is foreign to many of the companies who would, or should, be concerned. I subscribe to the school of competitive research. I feel that we have already gone far enough in the U.K. in the direction of co-operative work, and I should be unhappy to see the development of the equivalent of schemes such as the CRC here in the U.K. if it is to take place to the exclusion of more competitive research by individual companies. This is the crux of the problem. We have a large motor industry, and recently we have built up a large integrated oil industry. I think we would all agree that this has increased the need for closer liaison between the two. Possibly, this liaison would be most effective if joint sponsorship of research were involved. But I have a feeling that our first need is for more industrial research, competitively sponsored. Without this, we should be hard put to it to find the staff, the equipment, and the facilities to handle the co-ordinated projects, such as we have heard discussed today.

The authors of the four papers are all concerned with CRC, and they are all obviously, by their papers, enthusiastic about its work. I felt it my duty, therefore, to search for the other side of the picture. I have found it hard work. But I trust that in so doing, I shall not have given the impression that I am in any way critical of CRC, or in any way unappreciative of these four very fine papers.

J. H. Pitchford: Perhaps because of the nature of my work, I see the points of contact of the automobile and petroleum industries, rather unusually sharply.

For as long as I can remember, I have been surprised at the frequent instances of, one could almost say, ignorance in the one industry of what is going on in the other, and of the consequent loss and diversion of effort in the two. I agree with Mr Windebank that it is the greatest pity in the world to see competitive research dwindle because of the need to bring these two industries closer in their research projects, but I do not think that one really need conflict with the other.

In the motor industry, which I know perhaps rather more about than the petroleum industry, there is MIRA which has recently grown greatly in stature, and which might well represent, or be the body from which representatives might be drawn to represent, the motor industry on any body equivalent to CRC that may develop in the U.K.

There is, as Mr Windebank has said, the Institute of Petroleum. It has not quite the same position as MIRA which has, for example, its own research facilities, and these are increasing rapidly. The Institute of Petroleum is rather more limited in that respect. But the important thing is to get the body constituted that is going to operate on behalf of, and have the confidence of, the two industries. I picture a Committee or Council, call it what you will, composed equally of responsible people who have the confidence of their colleagues in each industry, and not too large in its numbers, possibly a dozen in all, or of that order, who could meet, and, in the early stages, draw up a programme of problems which beset the two industries in common.

As Mr McLeod said in his paper, what really determines whether a piece of research should be done or not is whether the industry is willing to pay for it. I could not agree more; it is an extremely important factor.

In MIRA there is perhaps the means and the channel for the money from the motor industry to find its way into such a co-operative research programme. As regards the petroleum industry, I am afraid I do not know its constitution well enough to say whether a similar body exists, from which funds could be made available to support research, but no doubt that point will come up in due course.

The fact remains very clearly that there is a need for such a composite body in the U.K. It will not fashion itself at all closely on the American pattern, because requirements are different in the U.K.; but what we can do, and what I suggest we should do, is to take the very fullest advantage of all that our good friends in the U.S.A. are most willing to tell us of their past experiences, their difficulties, and their problems in setting up such an organization. The establishment of such co-operation is no easy thing, as has been evidenced by the long time it has taken to grow in the U.S.A., and the set-backs it has suffered, and the difficulties it has had, but it has been achieved, and it now appears to be fulfilling an extremely useful function.

I think there is a feeling that such an organization should have its own research facilities. I rather doubt whether in the U.K., in view of the scale of our industry, we should think along those lines. Should we not perhaps think of being able to place our research projects where they could best be done, where there are people best qualified to deal with them, irrespective of the affiliations of the place where they may be done. There may be certain things that could best be done in the universities, others that may best be done in the laboratories of the petroleum industry, the motor industry, and so on. I do not think any such body ought to consider setting up facilities of its own at the outset—that is rather too ambitious—but time will tell and we shall see how that will work out when the time comes to discuss the details a little more fully.

The papers that have been presented have a great content which is of direct value to us in learning how to start this collaboration, and so stimulate even further an idea which is beginning to get quite a firm hold in the U.K. I have had the opportunity, as I said earlier, through the rather varied contacts I have, of seeing how people feel about this, and I am very encouraged that on all sides there is a definite and positive reaction, which might eventually develop along the lines I have outlined very roughly.

C. G. Williams: The U.S.A. is such a competitive country, that one's admiration is increased by the extent of the co-operation which has been achieved not only

between competitive oil companies but also between competitive automobile manufacturers. This raises the interesting question of how the Assignment Committee decides where to draw the line between subjects suitable for co-operative effort and those which should be left to the natural forces of competition. Is there any general guiding principle which is applied? Co-operation and competition must surely overlap sometimes. For example, I imagine that branded oil products are used in some of these co-operative studies, and inevitably specific makes of vehicles. While the object of such studies is undoubtedly to draw general conclusions, I imagine that specific points will inevitably arise regarding the performance or behaviour of individual oil products and vehicles, some of which may indeed be weaknesses. How are such methods dealt with? Presumably, there is agreement that no use to the detriment of any particular firm should be made of any item of information which might emerge in this way.

Looking at Mr Rendel's paper in particular, I see that CRC projects seem to fall under three main headings: first, the tackling of general problems involving an oil and vehicle relationship, then the development of techniques and test methods, and finally field tests. Dealing first with the tackling of general problems, such as volatility, which has been referred to, I get the impression that problems are only tackled by the CRC when they have already arisen, and that little or no attempt is made to anticipate problems. If I am right in that assumption, is that altogether wise? It would seem to me that the CRC provides a forum, where an exchange of information could take place between the two industries, on future trends, which might help to anticipate, and perhaps avoid future troubles.

Another principal activity of the CRC is the development of techniques and test methods. Here I noticed a statement in the paper that the CRC does not prescribe methods of test, nor engage in the writing of specifications. This seems to me to be undue modesty on the part of the CRC. The CRC may not put the stamp of officialdom on test methods, but I have the impression that the CRC, and the CFR before it, have been responsible for developing some of our most important test methods. For example, the CFR engine itself, the octane scale, and certain luboil test methods which enter conspicuously into certain specifications, *e.g.* the L1 and L4. I note that the present CRC programme does, in fact, include an extension of the octane scale above 100—the shape of things to come—and the development of oil test engines which may replace the old L4. Is it not a fact therefore that one of the important activities of the CRC is the development of test methods, which later may become standardized, and then incorporated into a specification.

The third activity of the CRC appears to be the carrying out of field tests upon quite an impressive scale. I would like to ask here whether in this sort of activity big vehicle operators such as bus companies participate in such field tests, and if so, whether the anonymity of products under trial is observed, and just how that is handled.

Finally, I would like to ask some questions regarding finance. I understand that the CRC itself has no research facilities. I presume, however, that there is a central fund, which covers administration. Is there in addition a central fund for general problems as and when they arise, which might be expended for example at a university? If so, and assuming that the figure is not confidential, it would be interesting to know the amount. Also, I presume that a major part of the cost of CRC activities is borne by contributions in kind; that is, by loan of staff, vehicles, and fuel. The paper contains the statement that "CRC consists of 700 engineers." Has any estimate been made of the total value of this contribution from the automotive and petroleum industries? My own guess, and I stand to be corrected, is that it runs into something of the order of $10 million p.a.

I imagine that special funds are allocated for specific researches, for example, on exhaust gas pollution. Are funds raised by making a special appeal to the two industries, and if so, is there a danger of dissipating goodwill by too frequent demands to the two industries of this kind?

All of us in the U.K. are anxious to learn as much as possible from this successful American endeavour.

M. K. McLeod: I presented a report to my Board of Directors in January of this year which answered, I think almost exactly, one of the questions that Dr Williams asked, *i.e.* the contribution that industry is making to CRC in terms of man-power. A survey was made of CRC activities during the year 1953, in which we asked each of the companies involved in CRC work to make an estimate of their contribution to CRC activity in terms of man-months of effort. Fig A presents an interesting summary of the information that was obtained. It shows that not quite half of the work that has been done within the CRC committees has been conducted by the petroleum industry, roughly one-third has been done by the automotive industry, and the remaining one-sixth is distributed across the other associated industries, research associations, and universities that are interested in our work.

The total dollar value of the man-power contribution is a little over $1 million. That figure was obtained by assigning a value of $20,000 p.a. for a man's work, full time, so that twelve man-months of activity would amount to $20,000. This figure is a little bit low, in that it involves only the man-power contribution in terms of time. It does not involve the contribution in terms of vehicles or fuels that are contributed to the project, but I would say that somewhere between this figure and perhaps $1,250,000 or $1,500,000 represents the industry's contribution to CRC activities.

It might be easier to explain our activities if I work back from our financial picture to the specific questions. Our CRC budget runs somewhere between $200,000 and $250,000 p.a. That covers the expenses of the CRC Headquarters, which is composed of myself and twenty girls, who go to the various technical meetings, record the minutes of the meetings, and carry out the necessary office functions. We hold approximately 250 meetings in a year. There is a considerable amount of travel throughout the U.S.A. The cost of our office staff covers about one-half of our budget. If we have a budget that runs to about $200,000, roughly $100,000 is involved in the expenses of my office. The other $100,000 is used for specific costs involved in carrying out our research programmes.

There are three general types of projects that are carried out within CRC. The first group consists of general projects, which are primarily those which do not have a specific objective, a specific scope, or a specific end. This classification includes administrative projects, and the development of new ones, from the time a study is initiated until it is known specifically what the scope is going to be, and how long it is going to take to do the job.

The second group consists of military projects, which are specifically conducted for the Ordnance Corps, or the Air Force, or the Bureau of Aeronautics, or the Bureau of Ships. These are initiated upon specific requests from the military, and are carried out by industry for them.

The third group covers projects which are carried out for industry.

The cost of carrying out these projects varies from year to year, and may go up or down 20 per cent, but would amount to approx $60,000 dollars for general projects, $100,000 for military projects, and $60,000 for industrial projects.

Expenses incurred in connexion with the general pro-

jects, the administrative work, and the initiation of new projects are covered by the contributions we receive from our two supporting industries. The API and the SAE each contribute $30,000 p.a. to the CRC activities, for the support of our general projects, and to keep CRC in business. That is the hard core on which the CRC operates—$60,000 p.a.

When we carry out projects for industry we have to prepare a programme, indicating that the work is going to be done in a certain manner, that it is going to cost a certain amount of money, and that it is expected that it will be completed in a certain length of time. We then go to industry and report that, if we are going to carry out these projects, CRC will require a certain sum of money to do that work. We do not, as CRC, ask individual companies for contributions. CRC cannot work for an individual company, we can work only for the two industries. So, in November of each year I present a budget to the API and the SAE, indicating that

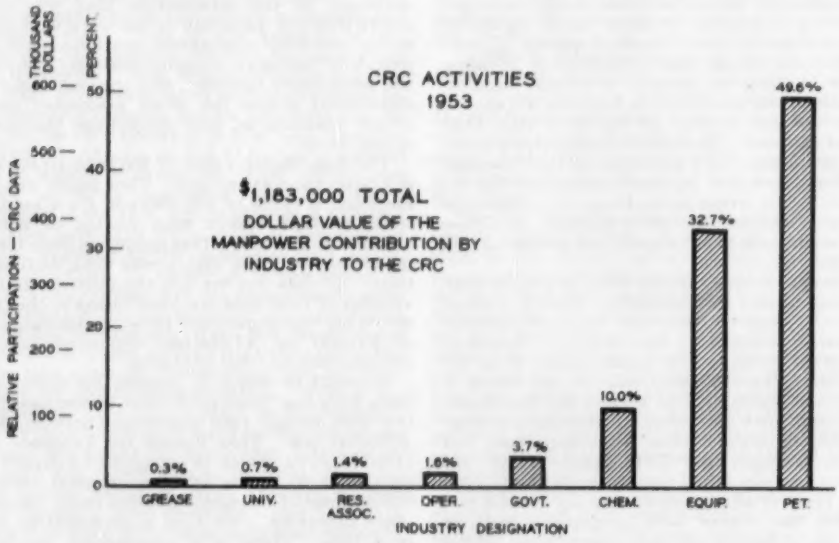


FIG A

our expected expenses for next year will be of a certain magnitude, of which a certain amount will be for general projects and an additional amount of special projects. An example of these industrial projects that we carry out is the CRC octane number requirement survey. Another one would be the work on instantaneous temperature measurement at the University of Wisconsin and the Massachusetts Institute of Technology.

We handle the military projects, which cost approx $100,000, in exactly the same way. After a direct request from the military has been received, we wait until the project has been developed to the point where we know specifically what we are planning to do; we have a scope and an objective; we know how long it is going to take us to do it; and we know how much it is going to cost. Then we go to the military and ask them to draw up a contract with CRC to carry out the work. During the second world war when CRC activities were 99 per cent for the military, we were very effective in carrying out work in this way. That, as I indicated in my paper, was one of the main reasons for setting up CRC activities, because we had to have corporate entity in order to enter into contracts with the military. Since then, the percentage of CRC activities undertaken at the request of the military has decreased, until at the present time it is somewhat less than 50 per cent of our activities.

There was a question as to whether CRC has a special fund for research that we would hand out to universities. The answer to that is "No." CRC is not in a position to act as a distributing agency for general research. We contract with research associations and universities to do work, but only after a project has been established, and a specific university has been selected, after a review of a number of them, because we think they are best equipped to do the job. We do not handle any projects in which we distribute money just for general research; it is only for specific problems.

In regard to the handling of branded products and the question of branded materials, CRC has an understanding with everyone working in our activities that all materials that are used in CRC investigations are coded. We give a code designation to a fuel or an engine or a vehicle, and, in conducting our work, we write all our reports on the basis of coded materials. We recognize, as I am sure that you all do, that it is necessary for some of the groups to know what these codes are. When we run tests, for example, in the octane requirement survey, we may run 25 Fords, 25 Chevrolets, 25 Lincolns, and 25 Cadillacs. When the original data are transmitted to the Analysis Committee, they are uncoded, but before the first preliminary draft of any report is prepared, a code number has been assigned to each individual vehicle, and no CRC report goes out with information on a branded product or branded material or vehicle, unless it is under code. When the report has been approved for distribution it is sent through the SAE or the API for general release. We then send to the management of the individual participating companies a special letter with a copy of the report. This letter to the vehicle manufacturer indicates, that of the vehicles tested, his was Car B, so that he can know how his car stands up to all the others, but we do not give the code to anyone else. With branded fuels and lubricants, we try to keep that information just as close as we possibly can, in that we ask the manufacturers who are supplying these materials to send them to the test sites in plain cans or plain drums, the only identification being a code number, which is assigned by the CRC.

One question was asked as to how the Assignment Committee decides whether a project is suitable for co-operative work. The answer to that requires a re-statement of the purposes of the Assignment Committee. The Assignment Committee of the CRC represents the management group from our two industries, and the members review each of our projects as it is proposed. From the petroleum industry side, we have a representative from the Automotive Research Committee of API, which acts as the gathering point for decisions from the petroleum industry. If a question arises as to whether a project is suitable for co-operative work, it will be discussed within the API, where the petroleum industry individuals, meeting by themselves without the automotive people around, can decide whether the project is suitable for co-operative activity, or whether it should be considered a competitive problem, and not transferred to CRC.

Similarly, in the automotive industry, there is a group that allows the automotive industry people to decide on their own as to whether a project should be co-operative or competitive, and when they meet, there must be unanimity of opinion. If the petroleum industry says it is worthwhile for CRC to work on a project, and the automotive industry also says so, then we can go right ahead with it. When it is a "No," then the project is not initiated by the CRC. We require unanimity within the two industries before we can initiate any work.

The question was raised as to whether we are perhaps using double-talk when we say that CRC does not work on methods of test, or write specifications, when we do, in fact, develop techniques. There is a very distinct difference between these two things, although perhaps it is hard for some people to understand this. It is necessary in almost all of our research work to have research techniques. We determine whether a technique is required for solving a specific research job, and on that basis decide whether a technique should be developed. We recognize that after a technique is developed, other people may use it and it may be used in some instances in the writing of specifications and to provide a mechanism for the buying and selling of products, but just because of this we cannot say that we do not need the technique for research purposes when we do. A method of test, on the other hand, is not necessarily required for research work, but is required to buy and sell products. We do not develop standards or methods of test to buy and sell products. I am not sure if I have made it quite clear, but it is certainly clear in our minds that we separate our research functions from functions of the public bodies for standardization work, such as the ASTM or the API or the SAE, or any of the other groups.

There is one other question that was raised, and that was the relationship, or perhaps the ratio, between the amount of competitive research and the amount of co-operative research. I am sure that that is something that individual companies, individual industries, and certainly individual people, must evaluate for themselves. I think that the figures given to you today, showing that roughly 1–1½ per cent of the total research funds, which went to co-operative activity in the U.S.A., are quite reasonable, at least for our two industries.

When we started out in 1922, there were only twenty people involved. Now we have 750. I am sure that it would not be reasonable to expect any group to jump into a large-scale co-operative research programme. It has to develop. I would like to endorse very heartily the comments of Mr Windebank, Mr Pitchford, and Dr Williams, that one of the biggest benefits that can come from this type of work depends on getting people together.

A. J. Blackwood: I am not sure if it is quite clear that participation in CRC activities by individual companies is on a strictly voluntary basis. If CRC undertakes a problem which is of no interest to a particular company, there is no necessity for that company to contribute either man-power or information to the project. I cannot recall a single research project in recent years on which my company has set up any special facilities or man-power to do the specific work which CRC was undertaking. Our contributions of information to the CRC have usually been cases where we were working in that area ourselves and considered that certain parts of the information were of a nature which could be contributed to the CRC; or it was in an area where we wanted to do the work, but just did not have the money or the equipment or the facilities to undertake it entirely on our own.

On the matter of specifications, we frequently lean over backwards to avoid getting into that type of work. There was a time when we felt that certain areas of CRC work were approaching very closely to specification writing. Our lawyers were quite concerned about it and made a very careful study of it. Certain changes of general CRC procedures were made and our lawyers today seem quite content to have us participate in their activities from that viewpoint. We do not consider that any of the work today is in an area where our lawyers would be particularly concerned.

On the question of what the ratio is between competitive and non-competitive research, Dr Sweeney's paper states that the petroleum industry was spending over $100 million p.a. on research. Actually, that is quite a conservative figure; it comes close, I believe, to about $140 million. Mr McLeod has clearly indicated in Fig A that the estimated cost of CRC work was about $1,100,000. So actually, it might be considered that considerably less than 1 per cent of the total petroleum industry research effort is going into non-competitive CRC type of research.

V. G. Raviolo: I have noticed that a word which we have accepted without question has become distorted in meaning during this discussion. That is, the word "contribution." We have begun to talk about contribution to CRC as if the participants were giving something away; as if they were making some kind of altruistic gesture to a group effort. It is not that kind of a contribution. If three of us find ourselves in a boat that is sinking, and we all start bailing to keep ourselves afloat, none of us is really contributing. We are each carrying our share of the load, and we are each doing something for our own good. If we do it well, with a joint effort, then we all stay afloat. I suggest we do not think of this "contribution" as a thing that is given away. It is rather something done to help ourselves in a much better way than we could if we stood alone.

Mr Windebank wanted to know how the competitive and the co-operative areas are kept separate. That arises out of a very natural situation. When we attend meetings, we not only meet formally in the committees, but usually we are together for several days, for example, at luncheon and dinner. Someone may say, "It seems to me that we ought to do something about a certain oil problem, because I see a lot of a certain kind of trouble with pistons." Then if his neighbour says, "Well, I am having an awful lot of trouble with pistons, too," and if three or four other people mention that they are interested in the same piston trouble, it begins to look like an industrial problem. But if somebody turns to that first man and says, "We do not have any trouble of that kind," and the next man says, "We have not heard about it," he soon discovers that he stands alone. He does not have an industrial problem, he has his own business problem, which he had better go home and work on.

If it is an industrial problem, if everyone is truly concerned about it, or if a group, at least, is concerned, they probably are engaged in some kind of effort to try to solve the problem. As soon as they discover that it is affecting

a great number of people in the industry, they realize that it is an industrial problem. At that point, they can pool their efforts. The only thing that they contribute is the work that they have already started on their own, which they need to prosecute as well and as rapidly as possible, and they gain by doing it in a concerted effort, rather than individually.

This brings us to the answer to the question from Dr Williams regarding anticipation. The idea of anticipating problems is excellent, but is very difficult to distinguish in advance between those which will be industrial problems and those which will be individual ones, and it will be hard to keep the work from getting a little bit academic. Actually, our competitive, individual efforts lead each of us off in our own directions. Ford goes one way, General Motors may take another direction, and inevitably there are some minor maladjustments. If those maladjustments are individual, we have our private problems, but if we find that the two industries are getting out of gear then we have a good co-operative project. The problem arises out of the drive for change because of competitive pressures. Should we try to anticipate problems, the natural thing to do would be to avoid the problem by avoiding change. Then you would have an institution devoted to maintaining the *status quo*, and that is never a good thing.

That leads me to the question that Mr Pitchford raised about the co-ordinated group having its own facilities. The direction that we take is to allow the CRC projects to come out of real problems in the field, which arise from our individual competitive efforts. Thereupon, we co-ordinate our individual research efforts with the entire group, joining with other people in order to expedite the solution of our own problems. It is apparent that this cannot be accomplished by using an artificial or separate research body. I think that the greatest emphasis needs to be put on the point that, without exception to my knowledge, all co-operative CRC work is done by people who are already engaged in the same work on their individual problems. We do not create a research project, all we do is to co-ordinate the effort which is already going on for the greater benefit of all concerned.

Dr F. T. Barwell : In common with previous speakers, I wish to emphasize that, in the U.K., we have a tradition of co-operative research, and I should imagine that, if an analysis of research expenditure over the whole of industry were made, we should find that co-operative research amounted to more than 1 per cent of our total effort.

Mr Windebank referred to MIRA, which, with its predecessor under Dr Williams, has made fundamental contributions to our knowledge of internal combustion engines and the factors governing their wear. That association draws much of its sustenance from DSIR, one of whose main objectives is to sponsor co-operative research in the U.K.

Much of the previous discussion has centred around the automobile industry. The basic problem before us was the conversion of the energy available in crude petroleum into the mechanical work emerging through the shaft of a prime mover. Because of the changing pattern of the demand for petroleum in its various forms, it was necessary to draw the proper balance between possible alterations in refining practice and changing fuel demands of power plant; not forgetting the parallel demand for fuel for heating. It would be equally uneconomic for the producers of power plant to set up a pattern of demand without refecence to the technical problems of supply as for the petroleum producers to consider only the economics of refining without reference to the factors governing the conversion of fuel to work. Governments have also a heavy responsibility because of the powerful effect of fiscal policy on the incidence of demand for the various classes of fuel. There would therefore be a wide measure of support for the author's proposal that the petroleum technologists and the mechanical engineers should co-operate in achieving the most economical means of meeting the demands for mobile power in the future.

Looking beyond the automobile industry therefore, we have BICERA, which, through its Fuels and Lubricants Panel, has co-operated with representatives of the petroleum industry and is doing valuable work on the utilization of fuels of lower grade in compression ignition engines. PAMETRADA has done much work on the gas turbine and the British Shipbuilding Research Association has concerned itself with problems of engines afloat. All these associations are united in their affiliation to DSIR whose own laboratories include the Fuel Research Station and the Mechanical Engineering Research Laboratory. The petroleum industry has not followed the lead of many other industries and set up a DSIR research association but BLOGRA is a step in the right direction. The Service Departments are also active in the field and encourage co-operation through development contracts and specialist committees to which representatives of industry and the universities are appointed. There are therefore many channels of co-operation already in existence. Their growth has, however, been haphazard rather than planned, and one of our main tasks this evening is to examine whether existing arrangements are adequate or whether there is need for improvement. In this connexion, we must not forget our shortage of scientific man-power and must be careful to avoid a situation wherein too many people spend too much time in committees rather than in constructive effort in the laboratory.

Our friends of the CRC have given us a great deal to think about and, whilst my personal view is that they are right in suggesting that there exists scope for improving the degree of co-operation in research between the petroleum and the users' interests in the U.K., the improved organizational pattern which will emerge will not necessarily conform to that which has been found desirable in the U.S.A. Finally, I would like to remind anyone who is actively considering the organizational steps necessary to improve co-operation, of the activities of DSIR in general and of BICERA in particular.

R. Vichnievsky : I would like to support the plea for co-operative work. In France, on the subject of fuel research, during the past three or four years, an important co-operative work was accomplished by the mechanical and the petroleum industries under the leadership of the French Petroleum Institute. The way was shown by the CRC organization. Our work began on the periodic control of the octane number determinations in different refineries and laboratories, not only in France but also on the Continent. We then made a rather important survey of the octane number requirements of French cars, taking into account more than 250 cars selected on the statistical basis. For this reason, our group has numerous contacts with CRC. We cannot say the same thing about our relations with the Institute of Petroleum. This body appears to be ruled by the law of mutual attraction, and I hope, in the very near future, with the help of my English friends we shall be able to amend this exception.

J. H. Weaving : We in the U.K. very much appreciate the very quick way in which the work of the CRC is published and the great benefit we have derived from it. I would, however, like to criticize the name of their organization: the Co-ordinating Research Council. Anyone well versed in American politics, knows that the CRC does not deal in wheat or cows, but apart from that the title does not help us in any way.

From the viewpoint of the automobile industry, I

feel that a need for a similar organization to CRC is long overdue in the U.K. This does not mean that in the past the problems have not been tackled. They have been tackled, but they have been tackled independently. It has been expressed that there are already too many committees. Of course, there may well be too many committees, but I do not think there are too many steering committees to direct research in the right direction, and this is just what the CRC does. There are plenty of committees, but surely with our lack of man-power we cannot afford any more duplication than necessary. Independent research work is necessary, and it does not hurt for two people to do exactly the same job, because we well know in our industry that they will not necessarily get the same answers! On the other hand, however, there is not room for a dozen people doing the same thing—we do not possess the man-power or the technical resources, and we ought to make the very most of our young men, to use their initiative most profitably, and also our money. We must therefore admit that both the automobile and the petroleum industries, although they have co-operated to some extent, shall we say on an individual basis, have not got together as much as they could have done. The consequence is, perhaps, that there is a little lack of trust between the two industries, though we are very polite when we meet each other in public, perhaps we are not so polite at our own private meetings; in fact, we have been known to be rude.

It has been pointed out in the discussion, both by Mr Pitchford and Mr Windebank, that if a new organization is necessary it has got to be justified. I feel that the authors of the four papers have really given us this justification; and I should like to pin-point a few of the problems that have affected us all. Most of us have suffered vapour lock troubles in the past; and again, comparatively recently, icing in carburettors, we should all have liked a quick answer to these troubles. A factor, in which the motor industry has not yet received a satisfactory deal, is the question of referenced fuels and referenced lubricants. We were better off, I feel, during the war, when we had four referenced fuels available, of definite known octane ratings and definite TEL content. Those particular fuels are not available today. There are referenced fuels, but there are not enough of them, and I do not think they are sufficiently specifically defined, and I feel that the same thing applies also, although perhaps not to such a great extent, to the lubrication field.

If we are to have a co-operative or co-ordinating body between the fuel and the automobile and aircraft industries, what are its terms of reference to be? Personally, I feel they should not be quite so wide as those of the CRC, for the reasons that have been stated by Dr Barwell and others. We already have organizations to do co-operative work in our field, in particular MIRA and BICERA. But it should be more specific and directed definitely to problems involving petroleum products and the industry using them, and not extended beyond this point.

As for its constitution, representation should be as direct as possible, in order that there will not be too much delay. If a problem has to go from the industry to one committee, and then to the co-operative body, then there would be a delay. So I feel therefore that the council, or committee, or whatever you are going to call it, should come directly from the two bodies, the petroleum industry and the automobile and aircraft industries, with representatives of all the appropriate co-operative bodies, from MIRA, BICERA, government departments, private organizations doing research (I have in mind, of course, the great work done by Ricardo's), and the Society of Motor Manufacturers and Traders),* so I feel a body constituted something like this would offer us very great help in co-operative work and would employ man-power to the greatest advantage.

D. Downs: The principal feeling engendered by hearing these four papers, describing the aims and activities of the CRC, is one of envy of our American friends for possessing such an admirable organization. Certain of us in the U.K., working in the border regions between the petroleum and the automotive industries, have long felt the need for a mechanism whereby these two often mutually suspicious bodies could be brought together around one table to discuss their difficulties and formulate a common programme for surmounting them. When I made this suggestion at a meeting of the World Petroleum Congress in Rome earlier this month, I was approached afterwards by a distinguished member of the petroleum industry, who suggested that it was unnecessary to make such an appeal to the petroleum body, but rather it should be made to the more recalcitrant engineers. Well, this is a meeting of petroleum technologists and automobile engineers, and the impressive support which the idea of co-operation has received from both sides suggests that no further persuasion is required to put the concept over.

We ought, however, to be giving serious consideration to the question of how this co-operation could best be brought about in the U.K. CRC has given us a useful lead in describing the mechanism found to work best in the U.S.A. It may be, however, that the rather different conditions obtaining in the U.K. demand a somewhat different approach. The exact mechanism of the co-operation is not so important as the will to co-operate. Once we get that, devising suitable machinery should not be too difficult.

While listening to Mr Rendel's impressive list of current CRC activities, I was led to ruminate on the first tasks which would confront a similar British organization. Certain of the problems are common to both sides of the Atlantic, and we in the U.K. would welcome the sort of information which the CRC makes available in the U.S.A. on the octane requirements of foreign cars. Atmospheric pollution is a subject which has been much debated, both in the U.S.A. and in the U.K. The road vehicle has only a certain responsibility for this, but in so far as it is involved, any investigation would obviously be a joint automobile–petroleum responsibility.

There is perhaps more interest in the diesel engine, particularly in the smaller size, in the U.K., and as this is a relatively new field, it is one which the petroleum technologists and the engine designer should take the opportunity of entering together. The extension of the field of utility of the diesel engine to the small van, taxis, and certain cars, units of approx 2 litres in approx four cylinders, and the coming dieselization of the railroads is going to increase the demand for the middle distillate fuels. One way of relieving that demand might be by extending the process that was started in the marine field of using the heavier fuels in the larger units.

If this process could be continued, such that auxiliary generating plant, and perhaps railway diesels, would use B-grade fuels, if not residual fuels, it would release more of the lighter grades for use in the smaller engines. Experience in the marine field suggests that this will not be achieved without a certain amount of difficulty, and it is an obvious field for close engine–petroleum co-operation. The fuel requirements of the very small diesel engines may themselves present problems. I do not think we know enough of them at the moment to say what would be the advantages, if any, of using a premium diesel fuel of high cetane number in these very high-speed engines. Chemical manufacturers are making available

* The Chairman might well be elected from the Institution of Mechanical Engineers one year and the Institute of Petroleum the next.

to us additives to improve the cetane number of diesel fuels. The assessment of the value of these new fuels and additives for these new engines is an obvious field for close petroleum–automotive co-operation.

I could carry on for quite a long time listing projects for joint consideration by the petroleum and automotive industries, and other speakers could no doubt add to the list. But I think that enough has been said to suggest that when such a body is set up it will not lack work.

M. Bourgeois: We do not know what has been the trend in the past few years about the automobile fuels in the U.S.A.

In Europe, and more particularly in France and in England, automobile fuels have changed during the past few years without any prior notice being given by the petroleum industry. Besides the increasing of octane number, the present fuels differ from those sold four years ago by the following changes:

(1) A material decrease in specific gravity, giving an increase of the volume of fuel consumed.

(2) Increase in volatility, which still tends to drawbacks, such as icing, vapour lock, and percolation.

(3) Alteration of the characteristics of gums resulting in troubles in the fuel feed.

The automobile industry, having received no notice of the changes, had to cope with the situation with the aid of any available means.

It would be of interest for the European automobile industry to know of the developments that are likely to take place within the coming years as regards fuels. Has the CRC had these questions in mind, and does it incorporate a department in charge of studying future developments regarding fuels in the future?

V. G. Raviolo: The CRC as such has made no study of gasoline trends into the future. However, here is an interesting aspect of one of the results of our co-operative work. Each one of us individually is interested in the same problem. Our friends in the petroleum industry come around individually to investigate our trends and interests. They know us well, we have established a good working relationship; we know they are discreet, and we know them thoroughly as individuals rather than as companies. We are happy to inform them fully (apart from the co-ordinated work, back in our home offices), because we trust their discretion. We do that with all of the people that we have learned to know who come seeking information. In turn, we as vehicle builders, go to our friends in the petroleum industry. Happily, they have learned that we are discreet, that they can disclose to us their individual plans. We are able to develop for ourselves some very real and accurate predictions of fuel trends which are useful to us in engine development. They are able to develop for themselves some real trends of changes in engines, which they can rely on. Primarily, the changes concern compression ratio, which would affect octane requirements. This situation arises from the co-ordinated work which develops these close relationships, but is actually no part of the CRC.

M. Ronayne: The previous speakers have emphasized the true value of the papers presented today and the need for considering in the U.K. a consultant body that would function here broadly in line, or perhaps in a modified form, as the CRC organization in the U.S.A.

There is, however, some lack of urgency in the approach to the general question of co-ordination between the petroleum technicians and the automobile engineers, and I would like to take this opportunity to put before you one important subject of concern to the engineers responsible for the present and future trends in the automobile industry.

The differential in the octane ratings of gasoline fuels available in the U.K. is very considerable compared with the U.S.A. These octane ratings (Motor Method) differ in the order of 9 here, between Regular and Premium fuels, compared with 2·5 in the U.S.A. and Canada.

In the U.K., a number of engines fitted in light commercial vehicles are basically the same as those fitted to cars. The lower grade Regular fuels are used in preference to Premium in this range because of the price advantage. Engines are, therefore, derated and performance correspondingly lowered, relative to overseas markets, which have higher grade Regular fuels available.

There is, therefore, an urgent need for a study of this situation, as there is a danger that the U.K. will have the lowest grade Regular fuel in the world, with the exception of some overseas areas, where I understand it is even lower than that available here.

Reference has already been made to the lead content of fuels, and the effect of any further increase with higher octane trends is also a matter of concern to the industry.

As the largest automobile exporting nation in the world, these present differences in overseas fuels relative to those available to the home market predicate unfavourably the engine requirements here by reason of the bigger separation of octanes between Regular and Premium fuels.

I would therefore submit that the industry does feel a real need for a consultative body such as the CRC, to provide a bridge between the petroleum companies and the automotive engineers, so that we have a link which will enable us to pose our problems and get, we hope, the sort of reaction we feel our friends in the petroleum industry can give us.

Mr Raviolo mentioned the relationship in the U.S.A., and I am quite confident the same sort of relationship exists in the U.K. today. I get the view that while we are good friends, we want those two organizations to pursue their courting, which I hope will end in an early marriage of their vast interests to the benefit of all.

Lt.-Col. S. J. M. Auld: In proposing a very hearty vote of thanks to Messrs McLeod, Rendel, Blackwood, and Raviolo, I am sure that Mr McLeod, as the leader, will allow me the privilege of suggesting that the absence of our good friends Dr Sweeney and Mr MacPherson have been well made up for by Mr Blackwood and Mr Raviolo respectively.

The vote of thanks was accorded with acclamation.

ENGINE TESTS OF LUBRICANTS

SPECIAL MEETING OF IP PANEL

A SPECIAL meeting of the Engine Tests of Lubricants Panel of IP Standardization Sub-Committee No. 5 (Engine Tests) was held on 1 July 1955. It was presided over by Dr N. Kendall, chairman of the Panel and among those present were the delegates of the CRC and representatives of organizations in Belgium, France, Germany, Holland, Israel, Italy, and Switzerland.

Dr N. Kendall: The original idea of this meeting was to enable the IP Engine Tests of Lubricants Panel, members of the CRC, and certain special guests, to meet and discuss technical details of the CLR engine, and the test methods which are being developed, or which it is intended to develop, on this engine. A large number of people showed considerable interest in the idea, and the meeting eventually attained its present size.

I would first like to welcome on behalf of the Panel our guests from the CRC in particular, from the U.S.A. in general, and from Continental Europe. I hope all will take the opportunity of getting to know one another better.

Most attended last night's meeting of the IP and learned then quite a lot about the CRC; how it grew up, what its aims are, what its activities and research programmes are, and what it means to the automotive and petroleum industries. The purpose of this present meeting is to discuss the details of the CLR engine and the test methods in which the CRC themselves are interested.

Although our primary interest is in the CLR engine, I would like to take this unique opportunity to say something very briefly about the corresponding activities of the Institute of Petroleum.

In the Institute, the overall direction on standardization is the responsibility of the Standardization Committee. Responsibility for the detailed specialist work, however, is delegated to sub-committees, of which there are at present fifteen, each of which is responsible for one specific aspect in the petroleum field. The active work of standardization is normally carried out by specialist panels which report to their respective sub-committees.

Within this structure, Sub-Committee 5 is concerned with Engine Tests, and one of its panels, the one with which we are concerned, deals with the engine tests of lubricants.

The responsibility of the Engine Tests of Lubricants Panel, is to standardize engine test methods for evaluating lubricants. The Panel, and indeed the IP in general, is not concerned with specification of product quality or the setting of levels of performance of a product in any way.

The composition of the Panel is such that it represents both government and commercial concerns, and we try to get on to the Panel all the known bodies who are actively interested or concerned in our subject, and who have something to contribute. The Panel, therefore, includes representatives of engine manufacturers and operators, petroleum companies, additive manufacturers, lubricating oil manufacturers, and official bodies, including members of the official Qualification Board in the U.K. In carrying out its work the Panel first adopts, or adapts, existing test methods, wherever they are deemed to be satisfactory and desirable for the purposes. Apart from that, however, we carry out active work of our own in developing new test methods; this is done by our Working Groups.

The Panel has already adopted the CRC L-1 and L-4 test methods and is in the course of adopting the 1-D test. Our interest in all these methods is that they are widely used throughout Europe for government and commercial purposes, and we consider that it is essential to have these methods in our standards book.

So far as new methods are concerned, we have become continuously more active within the past two or three years. In 1953, we held a Symposium,* the purpose of which was to gather together all the knowledgeable and interested people in the U.K. or abroad to find out what test methods existed, what test methods were used, and what test methods were recommended. We also wanted to ascertain what the consumer wanted, what the engine operator and the engine manufacturer were interested in, and what sort of test methods he wanted and why.

That Symposium was very successful and from that point, the Panel sat down to decide what they could sift out of the mass of information which came forward. The conclusion was reached that we would probably have to be concerned with quite a number of test methods. For a start, since we could not handle them all at once, we decided what properties in lubricating oils we wished to evaluate, which were the most important commercially at the moment, and which were the most suitable test methods to concentrate attention on initially. As a result, three test methods were selected—the Petter W1 engine bearing corrosion test; the Petter AV1 engine piston lacquering test; and the Gardner engine detergency test.

To handle all this work, two working groups were formed; one to deal with both the Petter AV1 and the Gardner test and the other to handle the Petter W1 test. Mr A. Towle is our chairman of the first group, and Mr C. O. R. Bell is chairman of the second. The activities of the group have involved a considerable amount of experimental work and discussion between a number of laboratories. It is of interest to reflect that such collaborative effort, in this single field, is entirely in line with the ideals of the CRC, as we understand them.

There is a third working group, the Operators' Working Group, the purpose of which is to deal with the day-to-day problems of those who are operating standard test methods. It assists them in getting supplies of spares of the right quality, in settling questions concerning piston ring finish, piston tolerances, and so on. It deals with methods of improving test control and repeatability, such, for example, as by the standardization of exhaust systems. In general, it is a practical working group dealing with any problems of operation.

Summarizing the aims of our Panel, these are two-fold. One is to standardize engine test methods for the evaluation of lubricating oils; the second is to assist and collaborate in a practical way with anyone who is interested in this field. These terms of reference are interpreted very liberally; we are always ready to assist anyone, whether or not they are members of the Panel, or indeed of the Institute, and from whatever country they come.

In line with this broad policy, we have for some time had communication with the CRC, and I hope as a result of the present meetings, we shall be able to strengthen

* *J. Inst. Petrol.*, 1953, **39**, 501–675.

the lines of communication. We already exchange minutes of our meetings and any details on test engines and test methods. Also representatives from the Institut Français du Pétrole frequently attend our Panel meetings as guests. Representatives of the Ausschuss für Ausarbeitung von Motorischen Prüfmethoden, the German organization, have also attended our meetings, and we have attended their meetings in Germany. So there is already a fair measure of interchange of information, and there is some measure of practical co-operation.

We are very desirous that this collaboration should continue and increase, and that those from other countries who feel that we can help them in any way will not hesitate to approach us on matters concerning the engine testing of lubricating oils.

Petter AV1 and Gardner Working Group

A. Towle, chairman of this Group, said: Following the 1953 Symposium on Engine Testing of Lubricating Oils the Panel concluded that sufficient experience was available on two diesel engines to warrant a co-operative detailed investigation being carried out to determine the suitability of test specifications written round these engines for consideration as IP standards. The engines selected were:

(a) *Petters AV1 Laboratory Test Engine*—a single cylinder unit of 3·15-inch bore and 4·33-inch stroke, *i.e.* 33·7 cu. in. swept volume, with an air-cell type combustion chamber and a substantial wet liner, developing approx 5 b.h.p. at 1500 rev/min.

(b) *The Gardner 1-L2 Laboratory Engine*—a single cylinder unit of 4·25-inch bore and 6-inch stroke developing approx 18·75 b.h.p. at 1700 rev/min.

The AV1 air-cell type engine had been in full-scale production at the Staines works of Petters Ltd, but had been superseded by a similar unit with direct injection. It is, however, available to special order. The latter could also be manufactured to special order by Norris, Henty, and Gardners Ltd, of Patricroft, Manchester.

The Working Group was, therefore, formed to consider these two engines and was composed in the first place of representatives of ten laboratories who would be able to run the AV1 (since increased to seventeen) and four laboratories who would operate the Gardner. At the time of this formation, approx 100 AV1 units were known to be in operation or in the course of installation (now increased to 160) as were two Gardner units (now increased to six).

The agreed terms of reference of the Group were:

(*a*) to organize a correlation programme as necessary;

(*b*) to determine the repeatability and reproducibility of test methods and assess the significance of the results;

(*c*) to compare the results obtained using the two engines;

(*d*) to submit progress reports to the Panel.

Four oils of known Caterpillar L-1 performance have been circulated to all participating laboratories for running in both engines. These consist of:

(*a*) a 2104B oil;
(*b*) a "borderline/failure" MIL-L-2104A oil;
(*c*) a "borderline/pass" MIL-L-2104A oil;
(*d*) a Supplement I oil.

The agreed test procedure on the AV1 is based on one which has been used for over 1000 tests by one laboratory, and consists of 120 hr running at 1500 rev/min and 80° C coolant outlet at a fixed fuel consumption using MIL-L-2104A fuel, with reversed flow kerosine cooling. Assessment at the end of the test is based primarily on piston skirt and land lacquer rating.

For the Gardner unit the agreed test procedure is based on one developed by another laboratory, and consists of a 130-hr test at 1500 rev/min and fixed fuel consumption, with 80° C coolant outlet. At intervals of 12 hr the oil is drained and weighed and new oil added equivalent to half the oil consumed during the preceding period. Assessment is based on the arithmetic mean of the rating of four separate areas of the piston. A 1 per cent sulphur fuel is used.

A recent meeting of the Group considered interim AV1 results from nine laboratories. Based on arbitrary limits established by one laboratory, and considering rating by individual laboratories in terms of DEF 2101A:

13 tests on oil "A" would be considered as "failure"; 5 as "borderline."
11 tests on oil "B" as "failure"; 4 as "borderline"; 2 as "pass."
3 tests on oil "C" as "failure"; 15 as "borderline"; 1 as "pass."
18 tests on oil "D" as "pass."

Rated by one man the corresponding results were:

15 tests oil "A" as "failure"; 3 "borderline."
8 tests oil "B" as "failure"; 9 as "borderline."
3 tests oil "C" as "failure"; 14 as "borderline"; 2 as "pass."
18 tests oil "D" as "pass."

It is hoped to consider further results at a forthcoming meeting, but it is obvious that the most serious difficulty is that of the degree of wiping to which the piston should be subjected when removed from the engine, since many deposits are of the same adhering nature. Experiments are in hand in all laboratories to determine the most satisfactory means of standardizing this.

The interim report of co-operative work on the Gardner from two laboratories, who had as yet been able to carry out the work, was also considered. This unit is obviously more workmanlike than the AV1, but difficulty has so far been encountered by one laboratory with excessive and inconsistent oil consumption which has tended to narrow down the difference between the oils. Investigations are in hand to correct this, and it is anticipated that at the next meeting of the Working Group results from four laboratories may be available.

Summarizing, considerable co-operative testing on the AV1 unit should be completed in the near future by up to seventeen British and Continental laboratories, and it is hoped it may be possible from this to develop a rough but very useful sorting-out test for oils. Further testing by the four laboratories concerned may indicate the possibility of using the Gardner as a primary test standard. The value of the work would have been much enhanced, however, if parallel with the laboratory tests it had been possible to carry out a series of service trials on the same oils.

Petter W1 Working Group

C. O. R. Bell, the Group chairman, said: The Petter W1 laboratory engine is a single cylinder, four-stroke, gasoline engine of 85 mm bore and 82·5 mm stroke, and in its normal industrial version it is designed to produce 3 b.h.p. at 1500 rev/min. It has the outstanding advantage that it is in current large scale mass production and this reflects very favourably on its initial cost and on the cost of spares normally consumed in lubricating oil tests. The quality of the great majority of the engine parts are quite satisfactory for lubricating oil testing in their standard mass-produced form, but where extra precision is required, *e.g.* in the cases of pistons, rings, and bearings, arrangements have been made with the manufacturers of these components for closer limits of inspection to be applied. This has resulted in the development of a test engine and procedure which

attempts to give the greatest possible value for money within its limitations. One way of looking at this, for example, is that it provides a means for experimental product evaluation or production quality control on a scale which may not be practicable if employing more expensive tests.

The test procedure now under examination by the IP Working Group follows closely that described in the paper presented at the Symposium in 1953. It is basically a high-oil temperature oxidation test similar to the Chevrolet L-4 test, and it was in fact developed to correlate with the L-4 test in respect of bearing corrosion. The jacket temperature employed is 150° C and, under these conditions, a full spread of piston skirt ratings from 0 to 10 is obtained between the most unstable base oils and oils of approx Supplement I standard. The test therefore gives an indication of detergency which when interpreted with care and some experience can be applied to making relative forecasts of diesel engine performance. This is valuable, since the test time is much shorter at 36 hr than most detergency screening tests actually performed on the diesel engine. It is not claimed or intended that this test should in any way make a diesel screening test unnecessary, but rather that its best use is found in helping to decide which of a number of formulations is worthy of further examination in the diesel engine. The results of the W1 and AV1 tests taken together, then, provide a good indication of the properties of the oil. The W1 test is basically an oxidation test. This feature has proved to be of great interest, as the oxidation stability of a blend as indicated by the viscosity increase of the used lubricating oil after test, has been shown to be indicative of relative lacquer performance in the diesel engine. It is in this connexion that the term "some experience" is used in relation to test interpretation. Generally speaking, the lower the viscosity increase in a series of oils of similar composition, the better will be their diesel lacquer performance. The comparison of the viscosity increase results on additive blends against those on the base oil used without additive can prove useful in the satisfactory interpretation of results.

In order to achieve the desired test conditions, some modifications to the standard production engine have been standardized by the Working Group. A crankcase door is provided to permit adequate cleaning of the internal parts between tests. A separate oil system permits the use of a reduced oil charge necessary in an oxidation test. The bottom of the crankcase is machined so that electric oil heaters can be placed underneath. A hot-spot heater is fixed to the side crankcase door and operated at 200° C to simulate the hotter conditions experienced in a multi-cylinder engine and to accelerate the oxidation process. A breather valve to regulate crankcase ventilation conditions is fitted. Means are provided for thermostat control of oil temperature and a standard position has been decided upon for oil temperature measurement. All these special modifications are now carried out by the manufacturer of the engine as a result of the work of the Group. The resulting engine is sold as the "Petter W1 Laboratory Engine" and costs just over £100 in its final form.

The work of the Petter W1 Working Group is not as far advanced as that of the AV1 Group, since the first phase has been the supply of suitable engines to interested parties. Some twenty-five engines of the modified type have now been delivered, and the majority of laboratories are still in the process of installation and establishment of these facilities. Prior to this, some thirty unmodified engines have been supplied for oil testing. A correlation programme has been organized in which nine laboratories have so far agreed to take part. Results have been received from two of these, and several of the others will soon be in a position to carry out the tests. A satisfactory number of results cannot now be expected to be received before the end of the year in order to make a final report to this Panel, as some laboratories will feel the need to gain a little experience with their engines before embarking on the correlation programme.

The Working Group has now held two meetings, and following the second one, a visit was made to the engine manufacturers' works at Staines, where members were able to see the engines being made and were able to make contacts with the manufacturers' personnel working on this project.

Engine Operators' Working Group

The chairman of the Group, **A. Towle,** said: Those engaged on engine testing of lubricants in the U.S.A. will agree that there is extreme difficulty even there in maintaining an up-to-date approach on the many problems which arise, including maintenance of supply and quality of spares, in agreeing on acceptable methods of rating and test procedures and on standardization of test fuels. These difficulties are magnified many times when the engines are being operated several thousand miles away from where they are manufactured and when spares are no longer on the doorstep. In the U.K. not only is fuel several times as expensive as in the U.S.A., but also import restrictions and the influence of import duty raise the possibility of producing these locally. Add to all this the fact that one is often attempting to parallel a "pass" standard which to the outside observer at any rate appears at times to vary its sights.

As a number of laboratories operating Caterpillar and Chevrolet engines for approval purposes in Europe grew, the logical outcome of this was the formation in 1954 of an Engine Operators' Working Group under the jurisdiction of the IP Engine Tests of Lubricants Panel. This is composed of representatives from each of the laboratories operating the engines. Meetings have been held every two months, and difficulties encountered have been discussed at length and many problems ironed out.

Included in the major points covered have been:

(*a*) a standardized system of injector and fuel pump reconditioning whereby laboratories forward these components to a centralized service agency and receive back their own reconditioned units accompanied by a test report at a fixed reconditioning charge;

(*b*) standardization of a smoke meter to be used on all Caterpillar tests and agreement on smoke limit standards;

(*c*) arrangements whereby a British firm maintains in stock supplies of British produced gaskets for all test engines;

(*d*) a common reclamation scheme for worn parts and agreement on bringing up-to-date earlier type engines;

(*e*) substitution of British produced pistons and rings, etc;

(*f*) negotiation through the Engine Tests of Lubricants Panel with the Ministry of Supply Lubricants' Advisory Panel on the question of acceptable test procedure;

(*g*) interchange of information on American test procedures which has filtered through to several British Companies from their American associates, including such deviations from written test procedures as are allowed in the U.S.A., but are not officially embodied in specifications.

All companies concerned have wholeheartedly co-operated on this Working Group and I believe that they all mutually agree on the benefits which have arisen from its introduction. It is proposed that in the near future its activities might be extended to embrace a general discussion on instrumentation.

M. K. McLeod, manager of CRC, then explained the design features of the CRC engine, his talk being illustrated by many lantern slides. A summarized version of the talk follows :

THE CLR OIL TEST ENGINE

By M. K. McLEOD

THE lubricating oil is an integral part of an internal combustion engine, and knowledge of the properties of the oil is vital if the engine designer is to take advantage of its capabilities and, conversely, to recognize its limitations. There is, at least at present, no set of physical or chemical descriptions that can picture for the engine designer, the engine operator, or the lubricating oil suppliers, how a particular oil will operate in the various engine types, under the various operating conditions, and with the various fuels which will be supplied.

The very complexity of the problem has probably caused the automotive and petroleum industries to move slowly in their basic lubricating oil studies. The vast number of dependencies make a rapid simple answer to this problem quite remote.

A variety of engines has been used for this lubricating oil research. The first of these were commercial engines of various sizes used to study individual problems. This led quickly to modifications of the commercial engines for the more general problems. Then came the use of small commercial single-cylinder engines, and, finally, the design and development of special engines specifically for lubricating oil research.

In 1949 the Co-ordinating Lubricant and Equipment Research Committee reviewed the need for an oil test engine which could be used as a research tool for the evaluation of engine lubricants. A Symposium on Laboratory Oil Test Engines was held, at which papers were presented describing the COT engine, the Gulf twin-cylinder engine, the Lauson engine, the 12·2 engine, and the Sunbury engine.

As a result of this Symposium, the Co-ordinating Lubricant and Equipment Research Committee, in 1950, organized the CLR Oil Test Engine Group which had two jobs. The first and immediate objective was the development of a substitute for the present L-4 test, and the second and long-range objective was the development of an oil test engine easily adaptable for use as a research tool to evaluate the various performance properties of lubricating oils.

The CLR Oil Test Engine Group divided its job into three parts :

(1) The determination of the design requirements.

(2) The design and construction of an engine to fulfil the desired design requirements.

(3) The development of the engine into a satisfactory laboratory tool for lubricating oil evaluation.

To carry out a survey of the interested laboratories, it was decided that a new technique of personally contacting the individual laboratories should be used, rather than the letter questionnaire. A Survey Team composed of men from both the automotive and petroleum industries visited a total of forty laboratories, including twenty-three oil laboratories, six additive manufacturers, six engine manufacturers, and five miscellaneous laboratories, and in each laboratory discussed the subject as completely as possible.

It was evident as the survey progressed that this method of individual visits was the best means of bringing out the ideas and needs of the organizations. Considerable time was spent in each visit making certain that all present were talking a common language. It would have been almost impossible to uncover differences in terminology and to get at the fundamentals of a laboratory's thinking through the earlier questionnaire method. The Survey Team developed not just " yes " and " no " answers, but the thinking and experience behind the answers.

The survey definitely established the need of both the automotive and petroleum industries for a basic oil test engine which could be used for research in the evaluation of lubricating oil performance, and which also could serve for routine lubricating oil testing or qualification.

A summary of the general design requirements is given below.

Engine Characteristics

A majority of the laboratories desired a cylinder bore of 3¼–4 inches with a stroke of approx the same size.

Speed Range

A max speed of at least 4000 rev/min was desired by practically all laboratories.

Compression Ratio Range

Gasoline : 7–12 : 1 in steps.
Diesel : up to 19 : 1.

Combustion Chamber Type

Overhead valve with provisions for optional L-head and diesel chambers.
Provision for an extra hole in the cylinder head.
Hardened crankshaft journals.
Sturdy connecting rod big end to minimize distortion.

Cooling System Characteristics

Separate head and block cooling.
Large cooling passages for either evaporative or forced circulation.
Wet cylinder liner.

Lubrication System Characteristics

Heat generation and dissipation as in current automotive multi-cylinder engines.
Wet or dry sump operation.
Small oil capacity.
Pressure and equivalent of splash lubrication.

Auxiliary oil jet piston cooling, aeration or oil consumption control.
Controlled positive crankcase ventilation.
Provision for full-flow or by-pass filtration.
Provision for measuring oil flow.
Generous deposit rating areas.

General Characteristics

Provision for auxiliary drives.
Provision for thermocouple locations.
Magneto or battery ignition.
Carburetion or fuel injection.
Easy assembly and disassembly and cleaning.
Precision in manufacturing.
Durability in operation.

It was decided that a pilot model of the engine should be built and, recognizing the need for close co-operation between the engine builder and the ultimate users, an experimental batch of engines would be constructed. Twenty-five laboratories volunteered to purchase these engines, sight unseen, and to participate in a co-operative development programme so that the production engines would be as useful as possible to industry.

The Laboratory Equipment Corporation, which was selected for the construction of the engine, prepared detailed drawings and lay-outs which were reviewed

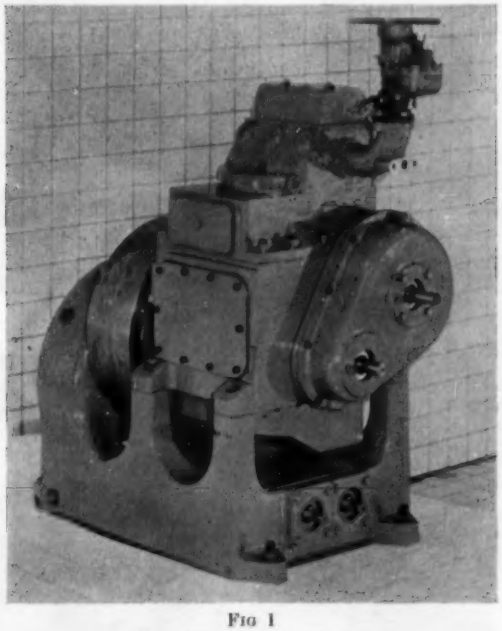


FIG 1
THE CLR OIL TEST ENGINE

by the Design Panel. Certain changes were recommended, and in November 1953 the Laboratory Equipment Corporation proceeded to construct the first pilot model engine.

This engine was built during the Spring of 1954, and was first operated on 17 May 1954, and completed its first 50 hr of endurance testing within a two-week period.

Photographs of the engine and its major components

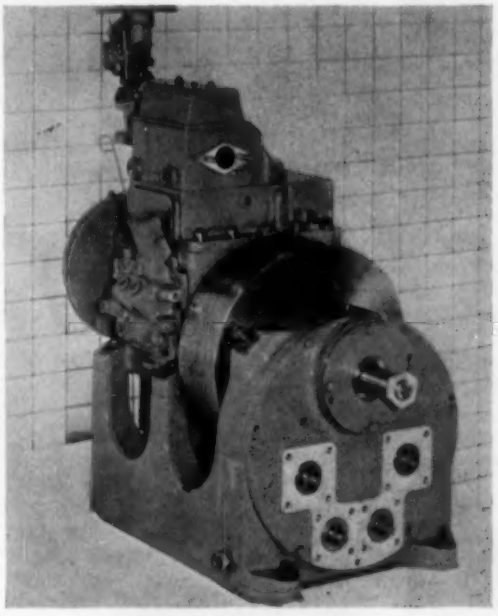


FIG 2

are shown in the accompanying figures. Fig 1 is a front quarter general view of the engine showing the straightforward design and also showing the cover plates which can be used for oil rating. Fig 2 is a rear quarter view of the engine showing the auxiliary drives on the accessory case and also showing the cover plate which contains all the oil control apparatus for the engine. By making this oil control section in the form of a cover plate, the oil pressure controls and arrangements for providing either full flow or partial filtration and the oil pump itself are included in a single item which can be readily removed from the engine for cleaning. Fig 3 shows the cover plates from each side of the engine removed, indicating the places on which deposit ratings can be made, and showing the oil pump and distributor drive on the oil control section cover plate. Provisions have been made for replacing the distributor with an electric dynamometer so that various loadings can be put on the distributor drive gear for the evaluation of wear characteristics of lubricating oils in this particular location.

Fig 4 shows how the cylinder head section of the engine can be removed for combustion chamber inspection. Four through bolts are used for the gasoline version of the engine. Provisions are made for the use of eight through bolts in the diesel version. Fig 5 shows the disassembly of the individual parts of the cylinder head and also shows the cooling pas-

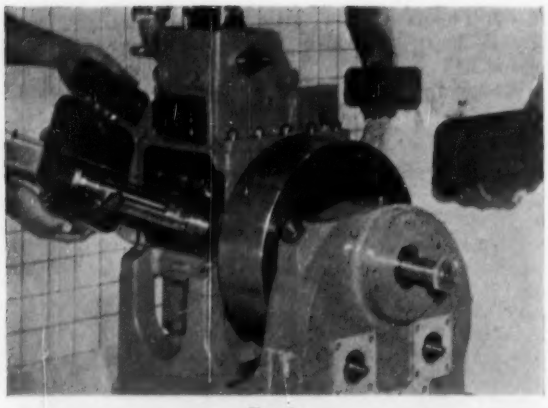


FIG 3

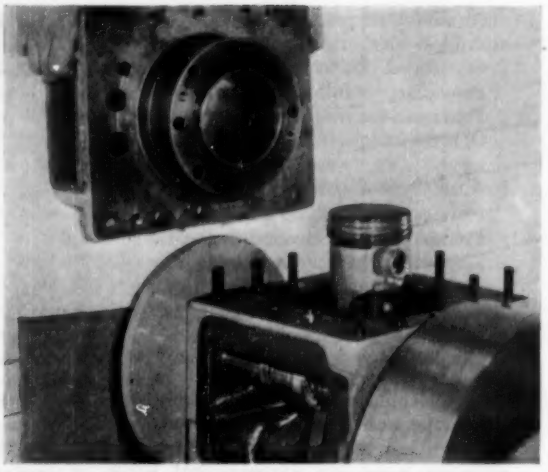


FIG 6

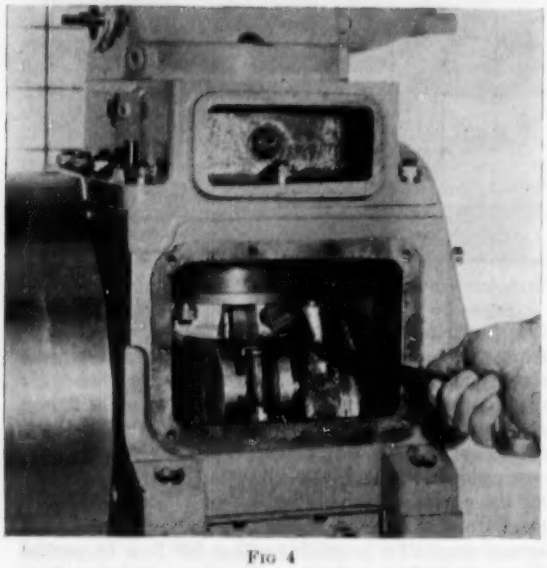


FIG 4

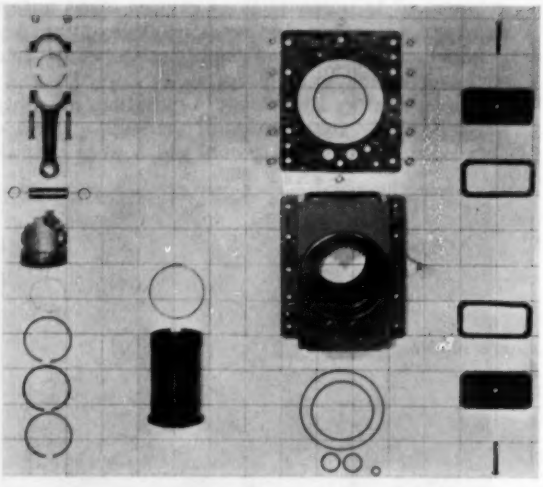


FIG 7

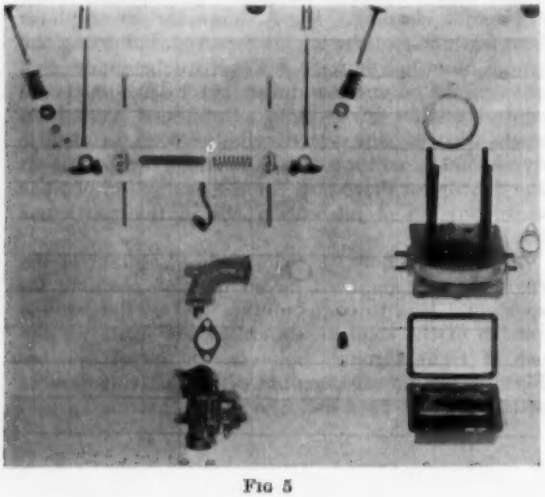


FIG 5

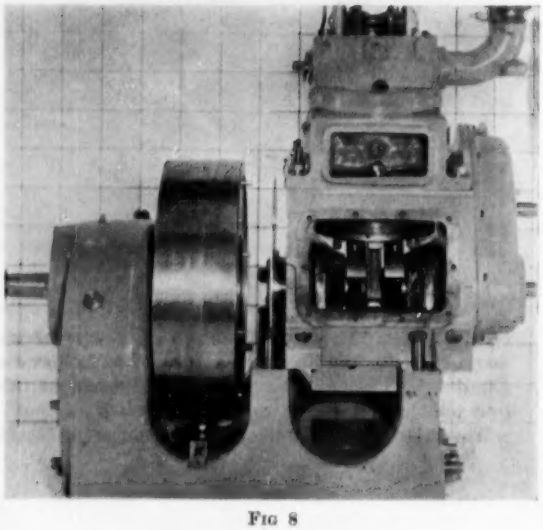


FIG 8

sages between the cylinder block and the cylinder head. By means of suitable gasketing, the cooling of the cylinder head and the cylinder barrel can be separated. Fig 6 shows how the cylinder and cylinder head assembly can be removed from the engine as a unit and, thus, permit an inspection of the piston without disturbing the ring set-up or the deposits at the top of the cylinder liner. Fig 7 represents a disassembly of the cylinder block assembly and shows the cylindrical cylinder sleeve which can be replaced easily for a study of the effect of the various design characteristics of the sleeve on wear.

Fig 8 demonstrates one of the features of this engine; how the power section can be disassembled from the accessory drive section and flywheel for cleaning and also to permit a second power section to be assembled on to the same base to keep a dynamometer continuously in operation. Fig 9 shows the crankcase section of the engine, from which will be noted the very heavy bearings and the rugged construction used to ensure long life of the engine. Fig 11 shows the balancing weights in the accessory drive case, and Fig 10 shows the chain drive from the flywheel to these balancing weights and the provisions

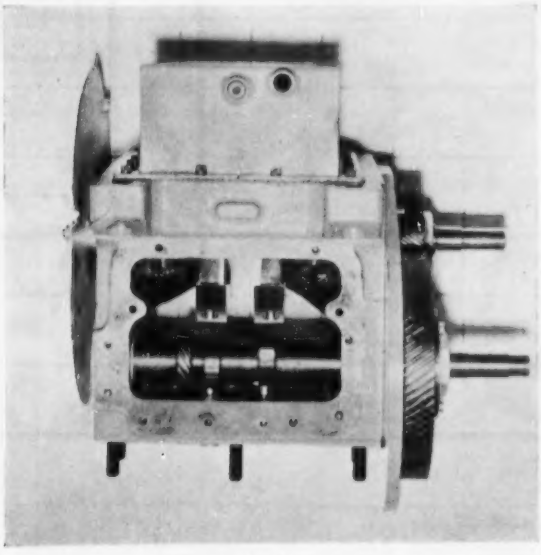


Fig 9

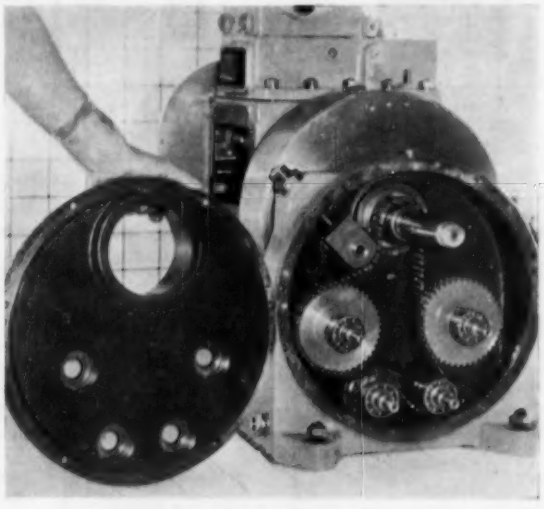


Fig 10

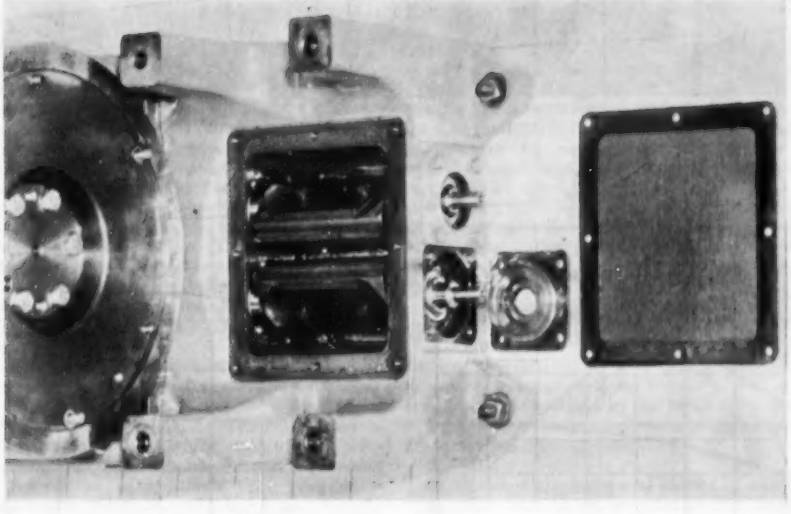


Fig 11

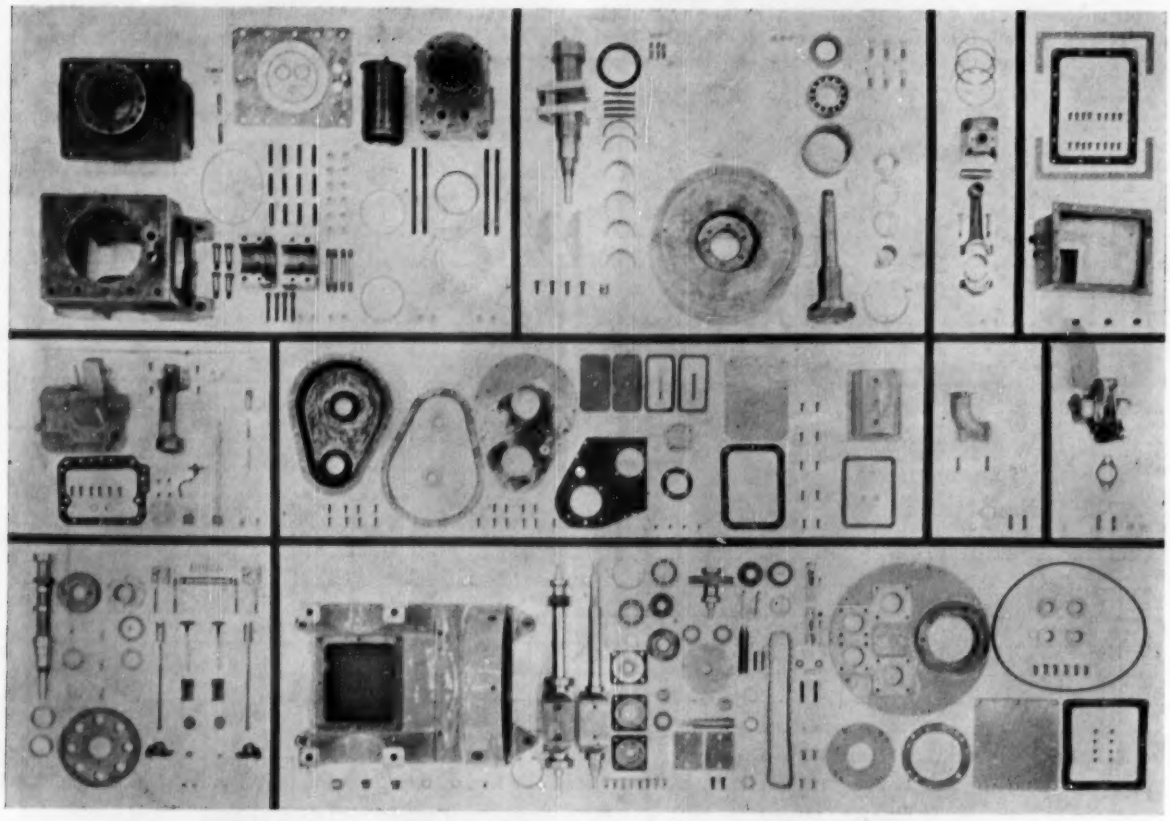


FIG 12

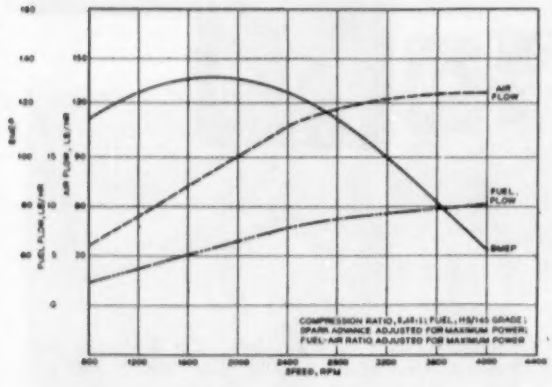


FIG 13

BMEP, FUEL FLOW, AND AIR FLOW *v.* SPEED

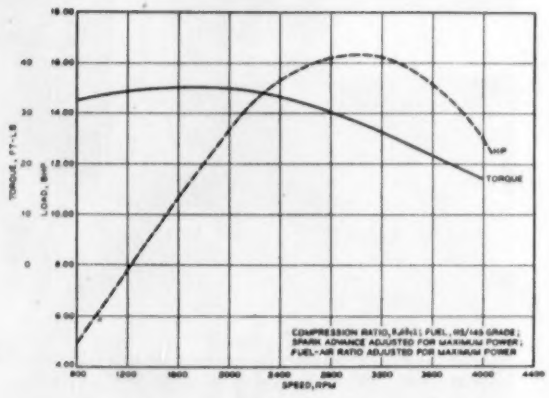


FIG 14

LOAD AND TORQUE *v.* SPEED

for the auxiliary drives coming out of the rear of the accessory drive case. Fig 12 is a complete disassembly of the CLR Oil Test Engine showing every piece that is used in the construction of the engine itself.

The first twenty-five engines, delivered during the latter half of 1954, are being used for performance checking of the engine and technique development studies by twenty-five individual laboratories representing both the automotive and petroleum industries.

To determine whether the CLR Oil Test Engine fulfilled the design requirements of simulating a modern passenger car engine with respect to performance characteristics, and to determine its ruggedness, one engine has been subjected to 400 hr of full throttle operation at speeds ranging up to 4500 rev/min. The balancing system was sufficiently accurate to permit the engine to operate at 4500 rev/min full throttle with practically no vibration; in fact, a coin could be stood on the end of the cylinder head during the test. Performance data on this engine are shown in Figs 13 and 14. It will be noticed that the friction mean effective pressure is somewhat higher than that which would be considered normal for a passenger car engine, but this is in line with other single-cylinder test engines, particularly when it will be remembered that oversized bearings are used.

A co-operative group has been established to develop techniques using this CLR Oil Test Engine for the various phases of lubricating oil evaluation, the first one being the development of a technique to replace the current L-4 test. It is too early to report on the test data which have been obtained, however, the general impression of the co-operating laboratories is that the CLR engine is doing a good job.

The final measure of the value of any piece of test equipment is its general acceptance by industry, not only in the U.S.A., but also in all other countries as well. It is, of course, too early to claim this for the CLR Oil Test Engine, but the whole-hearted and enthusiastic support of this project by both the automotive and petroleum industries research laboratories is almost a guarantee that general acceptance will be forthcoming. This will result in improved lubricants and improved engines, which is the underlying objective behind the expanding research effort in this field.

DISCUSSION

Following the above illustrated talk on the CLR engine by Mr McLeod the meeting was opened for questions which were answered by Messrs McLeod, Rendel, and Raviolo. The following is a summary of these questions and the answers:

Engine Details and Spare Parts

Q. What provision has been made for preventing the rocker box breathing into the crankcase if separate oil systems are used for the crankcase and rocker box?

A. The rocker box cover is a solid cover as it exists at present, and there are large holes leading down between the valve chambers into the crankcase proper. With the present common oiling system for crankcase and rocker box, the return oil from rocker shafts gravitates back to the crankcase via these holes, which also facilitates ventilation of the rocker box. If the rocker gear is isolated from the crankcase so that separate lubrication systems may be used, then the ventilation systems of the crankcase and rocker box will automatically be isolated.

Q. What is the valve timing and compression ratio of the engine?

A. The valve timing is typical present-day American practice. The compression ratio of the engine as used at present is a little over 8 : 1, but this can be varied over a range of 7 : 1 up to about 12 : 1. The compression ratio is varied by spacers under the cylinder block. With a compression ratio of about 8 : 1 the octane requirement of the engine, after it has been run for a time, is somewhat under 100 O.N.

Q. Assuming the engine is produced on the scale of the Caterpillar engine, what would be the cost of a complete engine and the cost of a power section?

A. The cost of a complete engine estimated on the first twenty-five which were built is $5000 and that of a separate power section is $2000. However, the design and development costs have all been included in the cost of the first batch of twenty-five engines, so that we anticipate a considerable reduction in the cost of complete engines and power sections for subsequent batches. Another point of interest is that the cost of a set of spare parts, which includes a piston, bearings, gaskets, etc., is estimated to be between $42 and $49.

Q. Has any progress been made to convert the engine for diesel operation?

A. It will be recalled that the design programme for the engine was started in 1951, but in the initial stages progress was slow. However, towards the end of 1952 it was announced by General Motors Corpn that they would not be able to supply Chevrolet L-4 engines after 1956, so that the greatest urgency was to develop the engine in order to have a technique to replace the Chevrolet L-4 technique by that time. In doing this it became mandatory to concentrate the effort on a gasoline cylinder head, and the first twenty-five engines were built with this in mind.

The conversion of the engine for diesel operation is number two priority, and it is hoped to start the design work this Autumn. In addition, work will also be put in hand to improve certain features of the present design.

Q. What injection system will be used for diesel operation?

A. The Design Panel has not yet established the details of the design, so that it is premature to state what injection system will be used, but it is believed that there is more interest in the swirl type of chamber.

Q. Does the ratio of the sump capacity to cylinder size bear any relation to practice?

A. Yes.

Q. What is the bore and stroke of the CLR engine?

A. The first batch of twenty-five engines have been manufactured with a bore of 3·8 inches and a stroke of 3·75 inches. It was decided to have a cylinder bore of 3·8 inches, as commercially produced pistons were available in this size which meet design requirements.

Q. Have any special provisions been made with respect to pistons, piston rings, skirt clearance, ring land clearances, etc., to control the amount of oil which passes the pistons? Also has any thought been given to the measurement of blow-by as a means of checking engine condition for test purposes?

A. The tests on the CLR were started using the piston

ring sets supplied by the manufacturer of the commercial piston, and these have proved to be entirely satisfactory. Piston ring manufacturers are represented on the group, and they have indicated that it is possible to change or modify the design of the piston rings so that the amount of oil passing the piston can be increased or decreased for research purposes.

The rate of blow-by is one of the test conditions which has been established by the group, and they have specified limits for satisfactory operation.

Q. During the description of the engine it was mentioned that the surface finish of the liner was 30–50 micro-inches r.m.s., which appears to be rather rough. Why was this finish chosen?

A. The finish which has been specified for cylinder liners is 35 micro-inches, but we allow a fairly wide tolerance and accept liners between 30 and 50 micro-inches r.m.s. It was decided to adopt this finish as it is normally used for the liners supplied with the commercial pistons which are used in the CLR engine. These liners and pistons are used in heavy-duty truck engines with complete satisfaction, so that their adoption avoided a large amount of experimental work.

Q. Has the mass of the flywheel been chosen so that there is a proportionate relationship between the inertia of the flywheel and the inertia of a car?

A. No calculations were made concerning the relationship of the inertia of the flywheel with that of a car. The selection of the flywheel size was determined primarily by torsional vibration characteristics of the engine.

Q. In addition to the pistons, are the valves, valve springs, etc., also standard equipment?

A. Yes, they are.

Q. Is it considered that commercial standard manufacturing tolerances are sufficiently close for lubricating oil engine test work? There seems to be some evidence from work carried out in the U.K. that commercial tolerances are not good enough.

A. It is very definitely felt that the engine cannot be operated satisfactorily for this work using normal commercial manufacturing tolerances. The Laboratory Equipment Corpn obtain the rough material from the suppliers and carry out final machining operations themselves.

Q. Have the Laboratory Equipment Corpn a European associate so that spare parts could be obtained in the U.K.?

A. This question has been discussed with some people in the U.K., but until there are engines running in Europe and it has been generally accepted as a routine engine no specific arrangements will be made. However, it appears that there would be no difficulty in arranging for an agent in the U.K.

Q. What special tools are required for servicing the engine?

A. It was decided to use socket cap screws wherever possible, as these have proved to be most satisfactory for engines which are stripped down at frequent intervals. With the exception of two special spanners the engine can be serviced with the standard American tools which every mechanic has. The special tools are torque wrenches for tightening up the connecting rod and cylinder head bolts. These special tools will be supplied by Laboratory Equipment Corpn.

The number of different sizes of socket cap screws has been kept to a minimum to facilitate quick assembly and dis-assembly of the engine. During the trial tests on the first engine to be built two of the group present dismantled the engine completely in 40 minutes. The dismantling and reassembly was completed in 2½ hr.

Q. What is the availability of spare parts?

A. This matter has been given careful consideration, and the position at present is quite satisfactory. Spare parts for this engine are just as easy to obtain as those for CFR engines. It is anticipated that the Laboratory Equipment Corpn will attach the greatest importance to the supply of spare parts, as by far the major part of the business will be the sale of spares.

Test Procedure

Q. At present, are you using the Caterpillar single-cylinder test engine for research work?

A. Very few laboratories use the Caterpillar engine for research work, as it is a big engine and requires lengthy test schedules. It is believed that most laboratories use smaller engines for research purposes.

Q. What is the total quantity of oil in circulation, and how many hours running will this allow on one charge of oil?

A. The total oil in circulation is one quart, which it is estimated will be sufficient for 48 hr operation without oil make-up.

Q. Are you of the opinion that tests should be made using only one charge of oil?

A. This depends upon the actual technique which is developed for evaluation work, but efforts were made to make the sump of the CLR engine as small as possible so that minimum quantities of experimental oils would be required. It is a simple modification to fit a larger sump which would allow tests to be run continuously and without the addition of oil make-up when testing oils from normal production.

Q. Is a standard design of exhaust system to be used in conjunction with this engine, and have the operating conditions been established for L-4 correlation?

A. Repeatability and reproducibility tests are now in progress to determine the effect of certain variables of engine operating condition on results. Exhaust system characteristics are among the variables which are being investigated.

At one of the first meetings of the CLR group a set of operating conditions were worked out and used for the first series of tests. The engine speed and power output were selected to correspond to Chevrolet L-4 conditions. It was decided to incorporate a surge tank before the carburettor to smooth out air flow, as a single-cylinder engine of this type tends to produce surges in the intake manifold. The spark advance, distributor cap setting, and type of sparking plug were standardized.

Among the variables which are being investigated is the jacket cooling system to be used. A number of laboratories would like to have employed evaporative cooling at 212° F, but another team has worked on water pump circulation at 180° F. It appears at present as though the latter system will be adopted, as it is neater than evaporative cooling and avoids the necessity for large condensers over the engine. Methods of controlling oil temperature are also being investigated, as one of the big items of concern is whether it will be possible to obtain sufficient sensitivity with respect to bearing corrosion using this engine. Three or four different methods have been tried, and the sump temperature which is aimed at is 280° F. This temperature gives a satisfactory corrosion level and adequate variation between oils of known Chevrolet performance in 20–36 hr. The problem at present is concerned with establishing an oil heating system which will give satisfactory repeatability and reproducibility. Indications are that an electric cartridge heater mounted on the side of the crankcase is the most promising.

Q. Many people are of the opinion that the Chevrolet L-4 conditions bear little or no relation to practical conditions, and that any new bearing corrosion test procedure should be correlated with service conditions rather than the existing Chevrolet L-4 test. What is the opinion of the CRC on this point?

A. We entirely agree with this criticism of the Chevrolet L-4 procedure, and we believe that this opinion is

shared by the majority of interested people in the U.S.A., but unfortunately events are such that it is not possible to do as we like. The original assignment was given to the oil test engine group to develop a test procedure or technique which indicates how engines operated in service. However, the military, to which the CRC is very closely committed, have had the Chevrolet L-4 test in their specification for many years, and as this test will be no longer available after 1956 we have had to subordinate our desires in order to help the military by having a procedure to replace the L-4 by 1956.

As soon as the present priority has been achieved we intend to inaugurate a programme to correlate with service as suggested, but this cannot be done within a year or even two years. We recognize the objections to the Chevrolet L-4 test, but in the circumstances we had no alternative to establishing correlation with this procedure as a first priority.

Q. It is believed that in Europe low temperature sludging is more important in many applications than high temperature conditions. Could this be borne in mind when new tests are being considered?

A. The CRC are actively engaged upon investigations into problems of sludging under low temperature operation. In order to find out whether this was a serious problem in the U.S.A., about six months ago contacts were made with the automotive industry, and it was found that it is an important problem. It is very definitely one of the items under consideration.

Q. Do you consider that it will be possible to have an alternative test procedure to the Chevrolet L-4 by the end of 1956?

A. Yes, we ought to have an alternative test, but it will not be standardized to the extent that it could be written up as, say, an ASTM test procedure. It should have reached the stage where it can be used as a research technique, and the results obtained should be comparable with L-4 results. In fact, this must be achieved to accomplish the assignment.

Q. Experience with the use of electric heaters to raise the crankcase temperature of engines for test purposes has shown that variations in results can be caused by differences in the skin temperature of different heaters, even though these have been of the same type. Is it likely that the use of electric heaters in the CLR engine will seriously affect reproducibility?

A. It had been hoped to do without an oil heater, but it was found that the equilibrium temperature of the crankcase was not as high as desired, so that additional heat had to be provided. We are fully aware of the possibility of getting into trouble by using an electric heater, and one of the programmes now being carried out by the group is to investigate three different ways of supplying the heat. These are the use of an electric heater on the outside of the crankcase cover plate, the circulation of a heated liquid through the compartment at the bottom of the sump, and the cartridge-type electric heater mounted on the side of the crankcase. The preliminary indications from the group are that the cartridge type heater is the most satisfactory. A number of oils have been tested using this method, and there has been no evidence that it has caused oil oxidation or decomposition. The rate of flow through the heater is very high, and the amount of heat passed to the oil is very low. The temperature rise brought about by the heater is in the region of 4° C.

Q. Has a means of increasing the churning of the oil within the engine by, say, additional gears been considered as a method of raising the oil temperature?

A. This is a possible way of doing it, but the splash from the gears on to the cylinder wall may give excessive oil consumption, and also aeration problems may result. If it is possible, it would probably be better to increase the size of the bearings and velocities through the system, rather than employ churning.

Q. It is well known that certain types of oils have been rated as unsuitable for particular purposes because they corrode copper–lead bearings when tested by the Chevrolet L-4 procedure, but these same oils are used in both gasoline and diesel engines fitted with copper–lead bearings in the field, and there have rarely been complaints of copper–lead bearing corrosion. In view of this there is considerable concern due to the fact that the CLR test procedure is to be correlated with Chevrolet L-4 results.

A. The chairman stated that this point had already been covered, the procedure is very close to American automotive engine practice.

Q. What variations have there been in oil consumption during the work completed to date?

A. Our experience so far is very limited, but with two engines which have been run for long periods the oil consumption has been very good. The engine which was run for endurance testing over 400 hr at full throttle gave an oil consumption within the acceptable limits as determined by passenger car operation. The oil consumption rates of the engines used in the Chevrolet L-4 correlation work have given oil consumptions proportionate to the L-4. Oil consumption is not considered to be a problem in our test work.

VOTE OF THANKS

N. Kendall: I would like to thank the CRC delegation for their very excellent presentation and for the very able way in which they have handled it and made it interesting. I would also like to thank our many guests, many of whom have travelled long distances to be here. I hope we shall see more of them in the future.

PRESENTATION OF IP AWARDS

At the Ordinary General Meeting of the Institute of Petroleum held at 26 Portland Place, London, W.1, on 12 October 1955, the Eastlake Medal was awarded to John A. Oriel, C.B.E., M.C., and the Honorary Fellowship of the Institute to Sir Frank E. Smith, G.C.B., G.B.E.

The presentations were made by Dr E. B. Evans, a vice-president of the Institute, who first expressed the regrets of the President that a visit to the U.S.A. made it impossible for him to be present.

THE EASTLAKE MEDAL

Making the presentation of the Eastlake Medal, **Dr Evans** said : " Mr Oriel has had an extremely distinguished career in the petroleum industry, besides being a very old friend of many of us. He joined the industry in 1921 and has served in Egypt, in Holland, and in the U.K., ultimately becoming general manager of " Shell " Refining & Marketing Company and chief chemist of The Shell Petroleum Co. Ltd. Today, he acts as consultant to the personnel administration of the Shell Group. He has done a great deal of work both for the country and for the industry, and during the last war he was active in the initiation and progressing of many important projects, in recognition of which he was awarded the C.B.E. in 1946.

" Mr Oriel joined the Institute in 1933 and first became a member of the Council in 1940. Since then he has served on many of the committees of the Institute and is chairman of the Education Committee. He was a Vice-President from 1943 to 1948 and again since 1953. He has done an immense amount of work behind the scenes and is one of our most active and distinguished members.

" The Eastlake Medal is awarded for long and meritorious service to the Institute by one of its members. It commemorates Arthur W. Eastlake, a co-founder of the Institute who served as Honorary Secretary for more than 30 years. It is very fitting, therefore, that a medal should be awarded to mark similar service by members of the Institute, and particularly fitting that this year's presentation should be made to Mr Oriel, who has done so much work for us. We can congratulate ourselves on our second recipient of this very important medal."

Mr John A. Oriel then accepted the Eastlake Medal from Dr Evans amid prolonged applause, and signed the Book of Honour.

John A. Oriel, after receiving the Medal said : " I want to thank you, Dr Evans, very much indeed for the kind words you have said about me and for presenting me with the Eastlake Medal. It brings a very warm feeling to the heart to be recognized in this way, however undeserved, after 35 years in an industry of which I am sure we are all proud to be members. I think that if it may be said of a great number of us of my vintage that we have devoted our lives to it, we would say it in the same way as an artist would say that he has devoted his life to art. It is a wonderful industry, it is one that is always forward-looking, full of interest. I have enjoyed every minute of it, and am proud to be a member of it. I am sure we are all proud when we can tell our friends and relations that we are oil men.

" Thank you again very much for what you have said and the Institute for granting me this honour."

THE HONORARY FELLOWSHIP

Dr E. B. Evans, presenting the Honorary Fellowship, said : " The second pleasant duty I have to perform is the award of the Honorary Fellowship of the Institute to Sir Frank E. Smith. Sir Frank has had a varied and an amazing career in both the scientific and the administrative fields. His early work started at the National Physical Laboratory and was concerned with electrical science. Following that he became the first director of research to the Admiralty and a little later secretary to the Department of Scientific and Industrial Research. Later on, in about 1938, he formed his first direct connexion with the oil industry, becoming scientific adviser to the then Anglo-Iranian Oil Company. During the war he was controller of telecommunications equipment for the Ministry of Aircraft Production and chairman of the Scientific Advisory Board of the Ministry of Supply. These things alone are sufficient to constitute a career for most people, but Sir Frank found time also to do many other things. For about nine years he was Secretary of the Royal Society, for about an equal period of time he was Honorary Secretary of the British Association ; he has been President of the Institute of Physics, President of the Physical Society, and has engaged in many other activities both in connexion with scientific societies and with Government and official bodies.

" His scientific achievements were recognized by his election to the Royal Society in 1918 He was knighted in 1931 and further honoured for his war and other services by promotion to the rank of Knight Grand Cross both of the Order of the Bath and a little later of the British Empire. His record of achievement is one of the most remarkable of any scientific man in Britain today.

" His association with the oil industry began in one sense with his connexion with the Anglo-Iranian Oil Company, but he had, of course, considerable knowledge of and contact with the industry during his period as Secretary of the Department of Scientific and Industrial Research. He was also at one time

chairman of the Road Research Board, which again is an organization which has considerable connexion with the petroleum industry.

"He has always been extremely helpful to the Institute, and on many occasions we have had the benefit of his advice and assistance in matters of a very varied character.

"The Honorary Fellowship of the Institute has previously been awarded only nine times, and I do not think we could find a more distinguished recipient of this award than Sir Frank Smith."

Sir Frank Smith then accepted the Honorary Fellowship, amid applause, and said: "I appreciate very much the honour which you have conferred on me and accept it with very great pleasure. As the chairman has said, my interest in life has been in research. I have been concerned with it, mainly industrial research, for over fifty years. Sixteen of these years have been spent in the petroleum industry and I have had great enjoyment and made very many friends in those years.

"My first contact with the Institute was when Professor J. S. S. Brame, who was then President, invited me to an Annual Dinner. Sir Thomas Holland, another President, also invited me as his guest to an Annual Dinner, but it was Sir John Cadman, as he then was, who really persuaded me to join the Institute. It is a very fine institute indeed, stimulating as it does, by publication of papers and by discussions, workers in research, petroleum and other engineers, and those interested in many other branches of science and technology.

"Petroleum is one of our most valuable liquids and yet we know very little about it. We neglect consideration of those electro-magnetic forces which cause atoms to join together to form chains and rings. Attention is, however, now being given to some of these problems and experiments on the bombardment of petroleum hydrocarbons with high-speed particles may open a new and revolutionary chapter in the history of petroleum.

"Mr Chairman and gentlemen, again I thank you."

CORRESPONDENCE

The Editor, *Journal of the Institute of Petroleum.*

SIR,

I should be grateful if you would allow me space to comment on Dr A. S. C. Lawrence's recent review of "The Solvent Properties of Amphiphilic Compounds" in your September issue.

Although generally favourable, this review attributes to me certain sins of omission and commission of which I am not guilty, as a more careful perusal of my book would have shown.

In the first place, Lawrence makes the curious remark: "There is reluctance to use phase rule discipline; for example, when a Type III solution suddenly appears and is described as of theoretical importance; and this is also seen in loose nomenclature such as 'liquid crystalline homogeneous G phase or gel,' and 'micelles or "cybotactic" complexes.'"

Actually, I have not referred to a "Type III *solution*" at all but to a "Type III *system*," *i.e.* to a three phase system, as shown in Fig 3.11, p. 68, consisting of an isotropic "solubilized" phase in equilibrium with excess organic and aqueous liquid phases. As discussed on pp. 68 and 111 these three phase systems are of great significance from a structural point of view. They do, of course, like all systems in thermodynamic equilibrium, conform to the phase rule, but this does not, as Lawrence seems to imply, detract from their significance in respect to intermolecular architecture.

As regards nomenclature, in writing "liquid crystalline homogeneous G phase or 'gel'" (Lawrence omits the quotes from "gel") I wished to point out that the phase which in earlier work I described as "gel" on account of its consistency is more precisely to be identified as the liquid crystalline homogeneous G phase. In writing "micelles or 'cybotactic' complexes" I wished again to signify that the two terms may be regarded as synonymous. There is no looseness of nomenclature here nor can I see the alleged further reflection of my "reluctance to use phase rule discipline."

Of more importance than the above is Lawrence's assertion that: "There is no statement anywhere, nor illustrations of the evidence on which Winsor decided that his G phase was liquid crystalline; no mention whether smectic or nematic—a point of the highest importance since the smectic is, as he draws it, a layer lattice whereas the long axes of the molecules in the nematic phase have an imbricated arrangement which precludes layer sliding upon layer. . . . There is mention of streaming birefringence of this phase but this is not a liquid crystalline structure."

It is true that I have not frequently used the word smectic (*cf*, however, p. 187 footnote) which, after all, in its derivation means only "soap like." I have preferred to use the more descriptive term lamellar. The connotation is, however, identical.

I have emphasized the lamellar, layer, or "smectic" character of the liquid crystalline G phase, both at the first mention of this phase (p. 8) and throughout the book (*cf*, *e.g.* pp. 17, 64, 185) and fully agree with Lawrence that this is a point of the highest importance. Apart from the general theoretical principles which would lead one to expect a lamellar structure for this phase (*cf*, *e.g.* p. 17, 64), the main experimental evidence in its favour lies in the X-ray work, and this has been quoted in some detail on pp. 185 *et seq* with the relevant X-ray diagrams.

Lawrence's complaint that there is no illustration of the liquid crystalline character of the G phase is without basis. In Fig 3.1 (p. 58) showing a series of solubilized systems photographed between crossed polaroid sheets the permanent birefringence, and thus the liquid crystalline character, of the G phase is very clearly illustrated and contrasted ((4) and (6) Fig 3.1) with the optical isotropy of the conjugate S phases. Further, the persistence of the orientation within the liquid crystalline phase which is illustrated in Fig 3.1 is expressly noted both in the legend to this figure and in the text (p. 185).

I should point out that nowhere do I "mention" that the G phase shows streaming birefringence. Such a statement would be incorrect. Permanent birefringence, not streaming birefringence, is characteristic of the liquid crystalline phase. Streaming birefringence is shown, not by the liquid crystalline phase but by certain isotropic systems (pp. 36 *et seq*, 184). It seems likely that these systems probably consist of stable clear emulsions of the S and G phases. Under resting conditions, the G phase in these emulsions is, overall, randomly oriented owing to Brownian motion and the emulsion appears istropic between crossed polaroid sheets. With suitable examples, on gentle streaming the particles of the anisotropic G phase become oriented and the emulsion lights up when viewed between crossed polaroids. I have discussed this streaming birefringence at length on pp. 36 *et seq* in connexion with the structure of viscoelastic soap solutions.

Finally, Lawrence states: "The most curious feature of the work is that it is all concerned with systems in which the concentration of soap is high and so we get no lead through to ordinary emulsification conditions." In the absence of a definition of "high" this statement has no precise significance, but the concentration range considered in the book is wide. It is hardly "curious," however, that a book dealing with "solvent properties" should not deal with "emulsification conditions." To form stable emulsions it is important that a "soap" should be present at a concentration below that at which it permits a

significant amount of the dispersed phase to become solubilized in the continuous phase. If it is present above this concentration a path is provided whereby molecules of the disperse phase may pass from the smaller to the larger droplets. This thermodynamic tendency can then become an effective mechanism for emulsion breakdown. None the less, the emulsifiability in water of solutions containing " high " concentrations of soaps, etc., is practically of great importance in connexion with the formulation of cutting oils, insecticidal dispersions, etc. It has been discussed on p. 81 and indicated on relevant diagrams.

Yours faithfully,

P. A. WINDSOR

Kelsall, Cheshire,
18 *October* 1955

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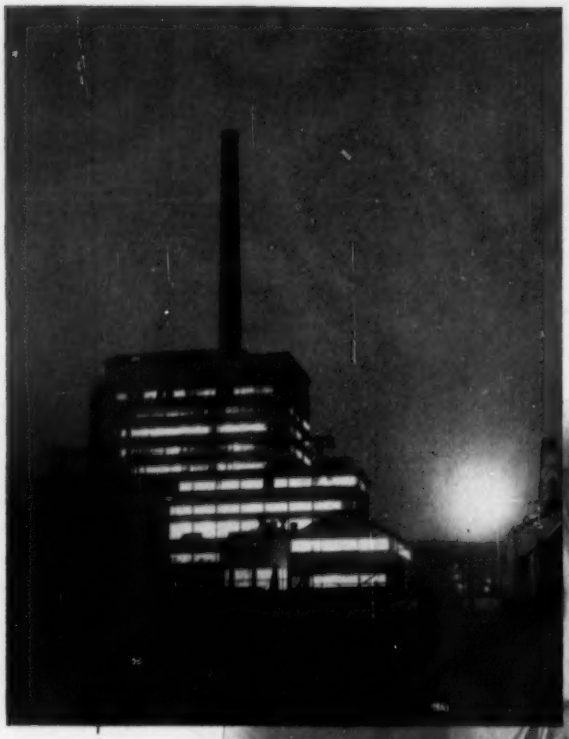

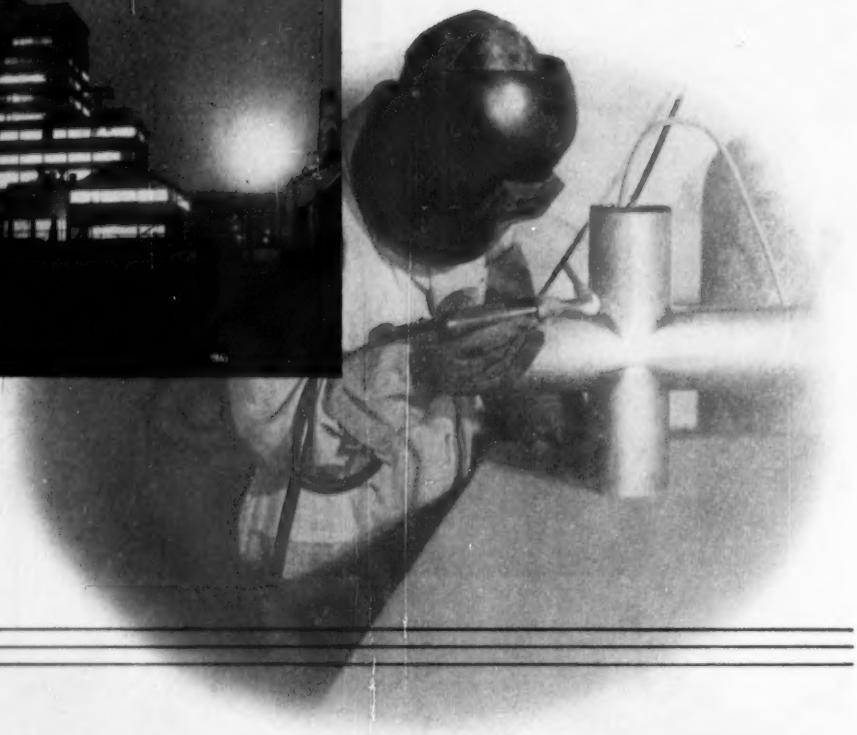

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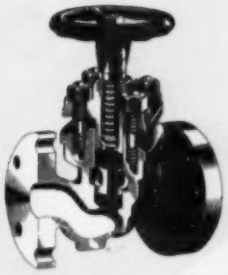

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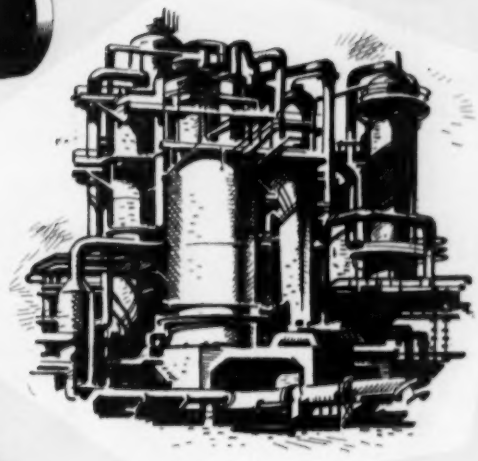

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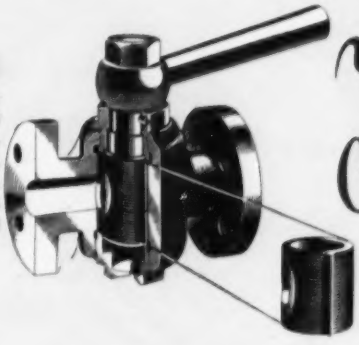

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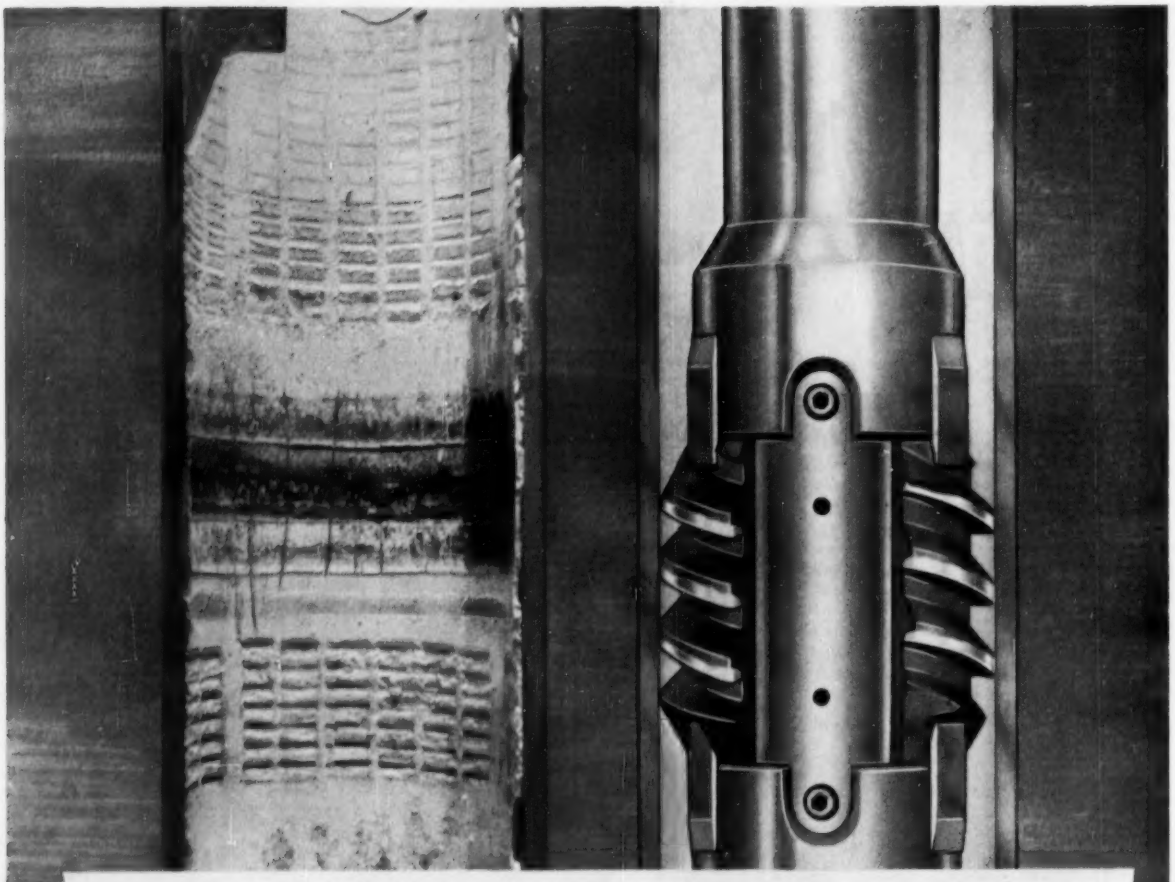

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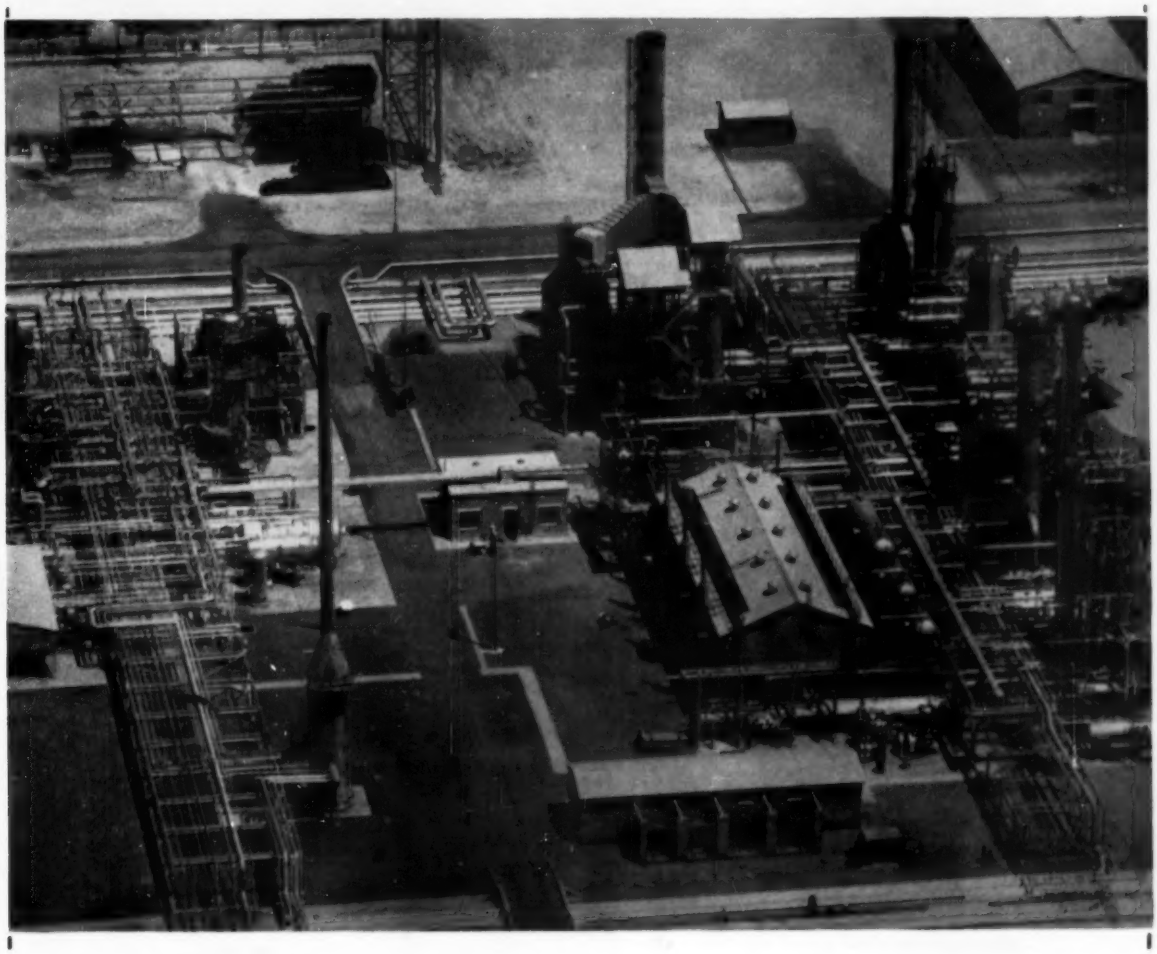

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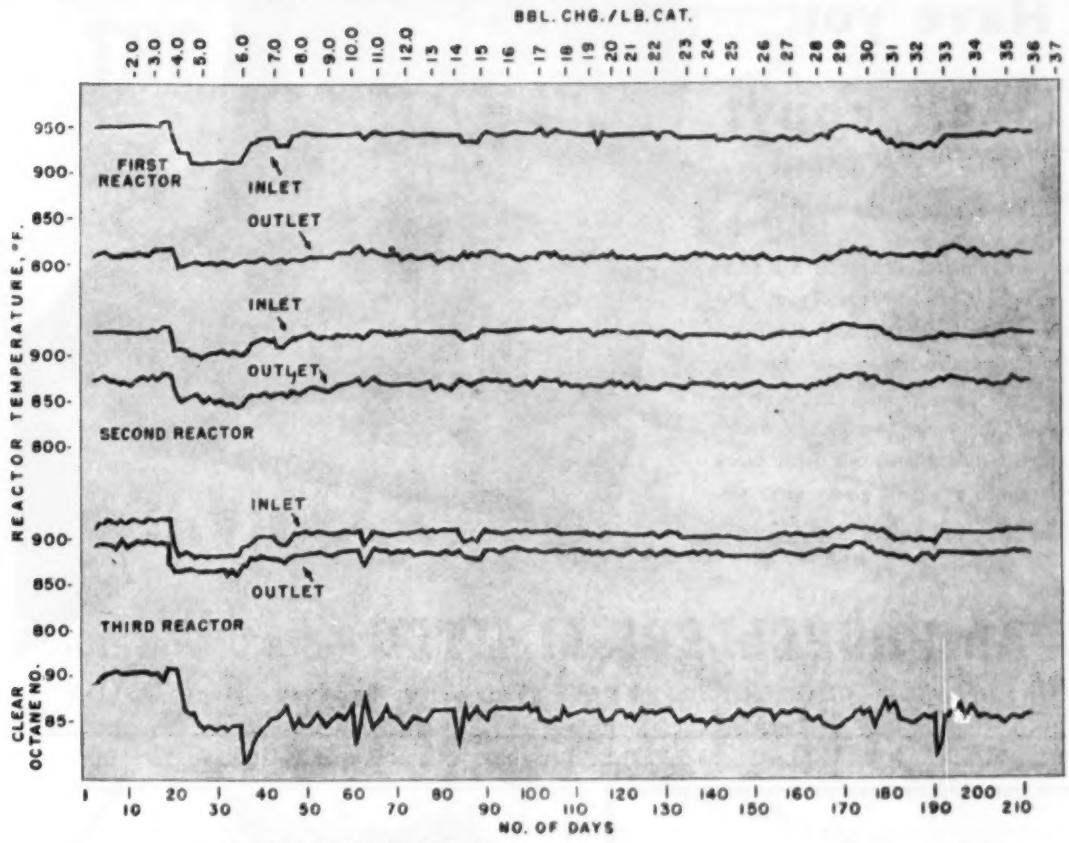

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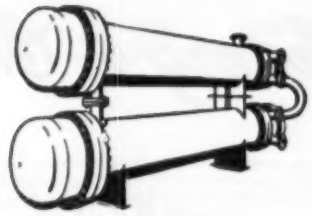

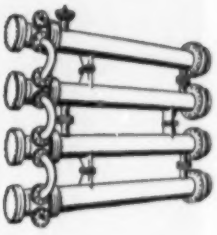

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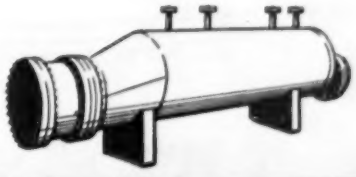

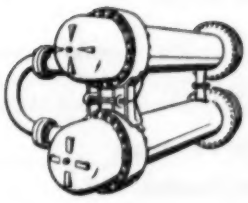

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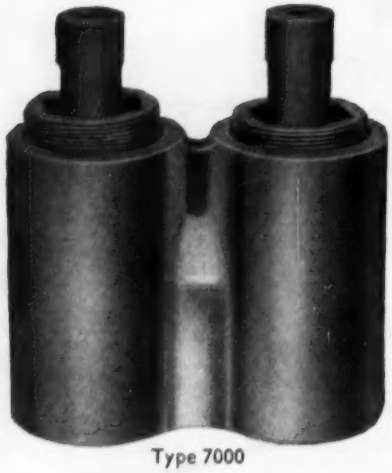

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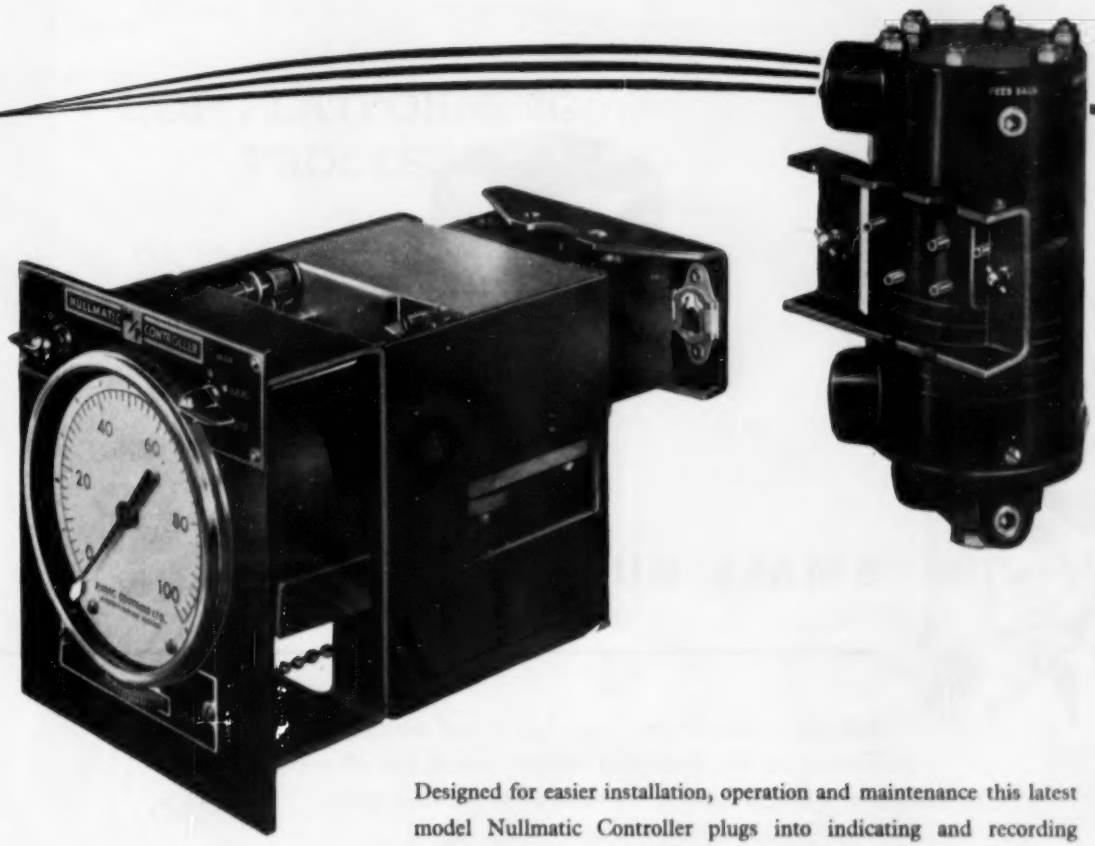

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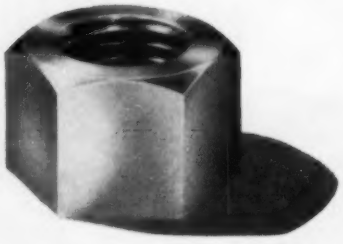

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It's just a simple hex nut—but it can easily prove vitally important to the successful completion or the efficient operation of a single unit or a complete processing plant.

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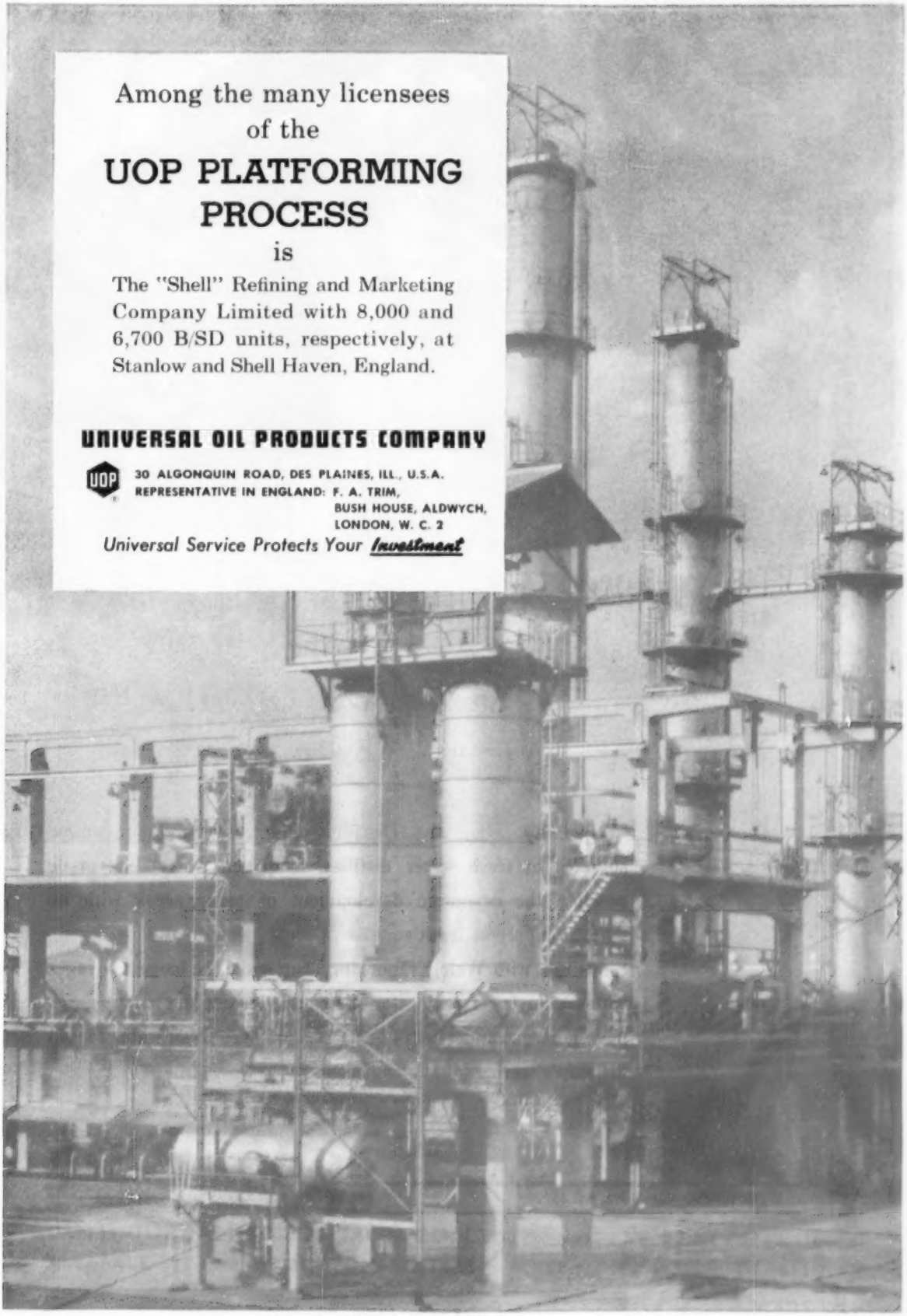
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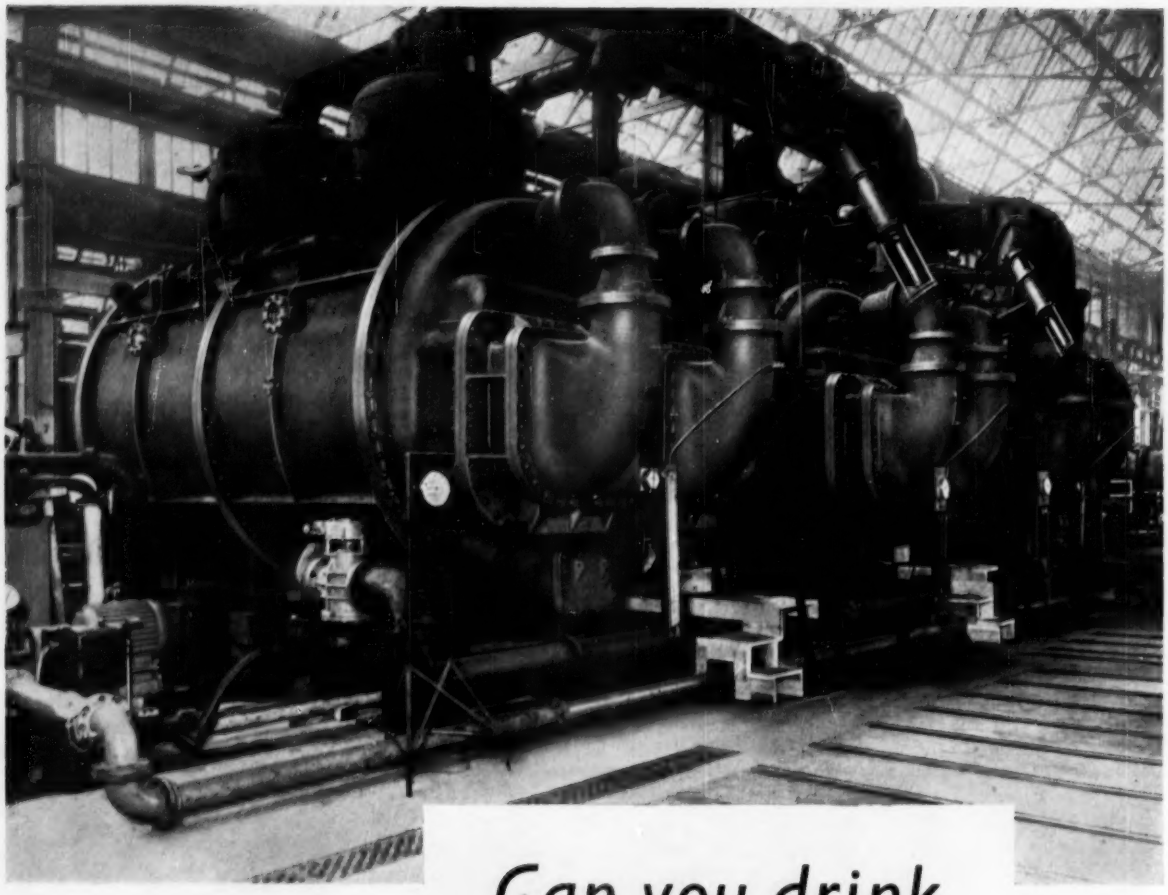

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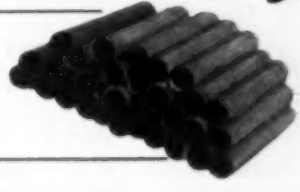
Illustration shows South Durham steel pipes being off-loaded into barges at Basrah for transport to site for installation in the Basrah Petroleum Company's new 24 inch pipeline.



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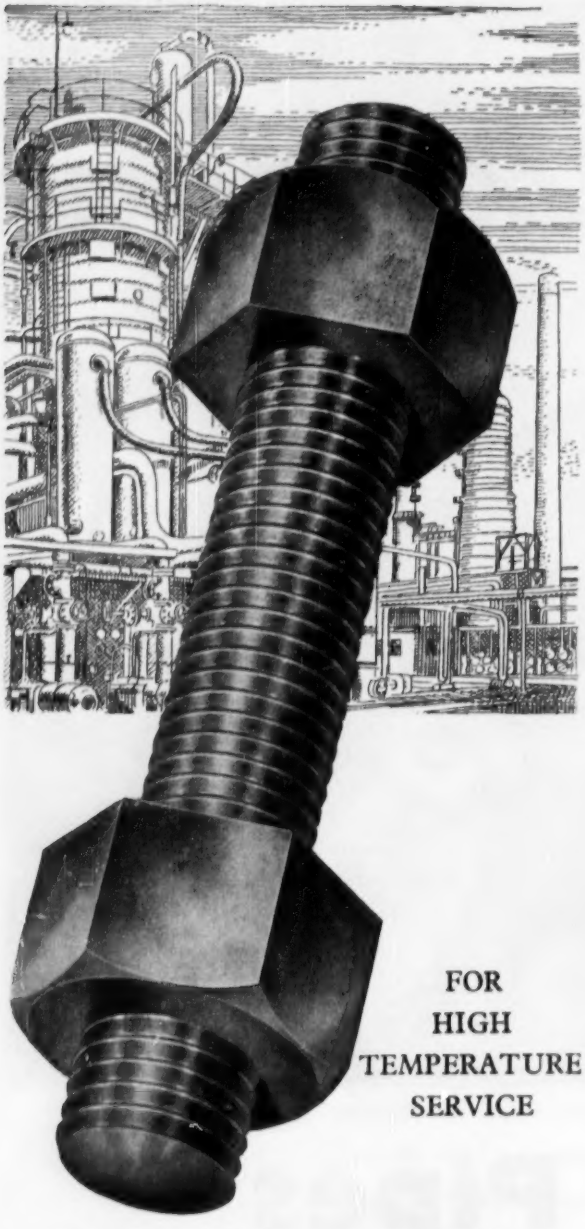

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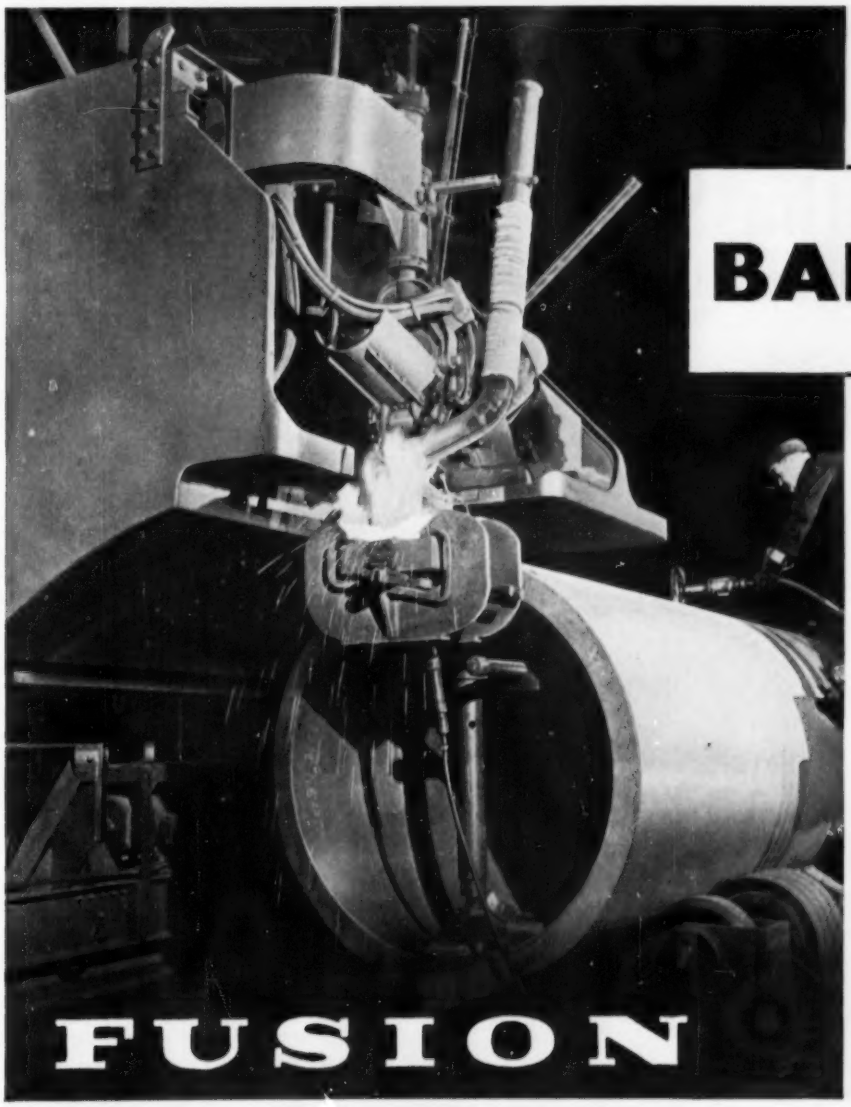

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Naphtha Stabilisation Unit

Naphtha Stabilisation Unit at the Esso Refinery at Fawley—designed and built by Foster Wheeler.

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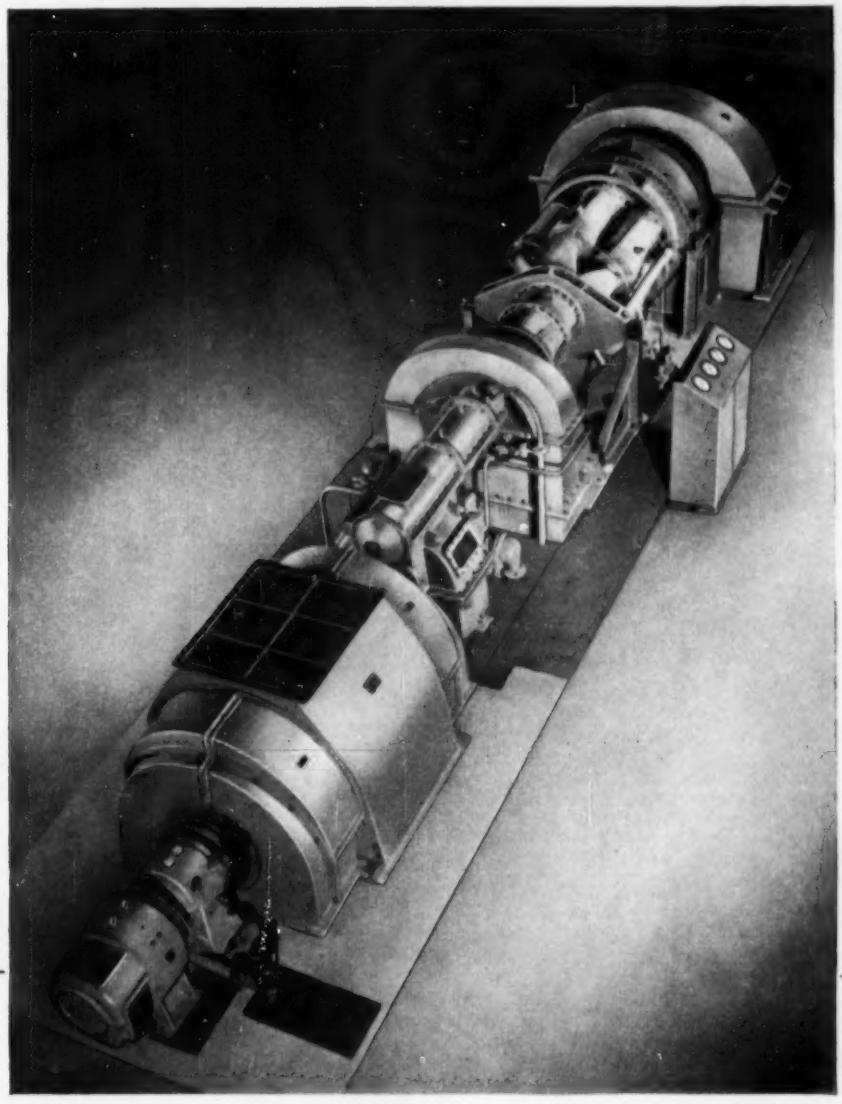

Gas Turbines *for Power Generation*

The generating set shown above as installed in the Ashford Common Power Station of the Metropolitan Water Board. Rated at 2,500kW, is to serve as a stand-by unit.

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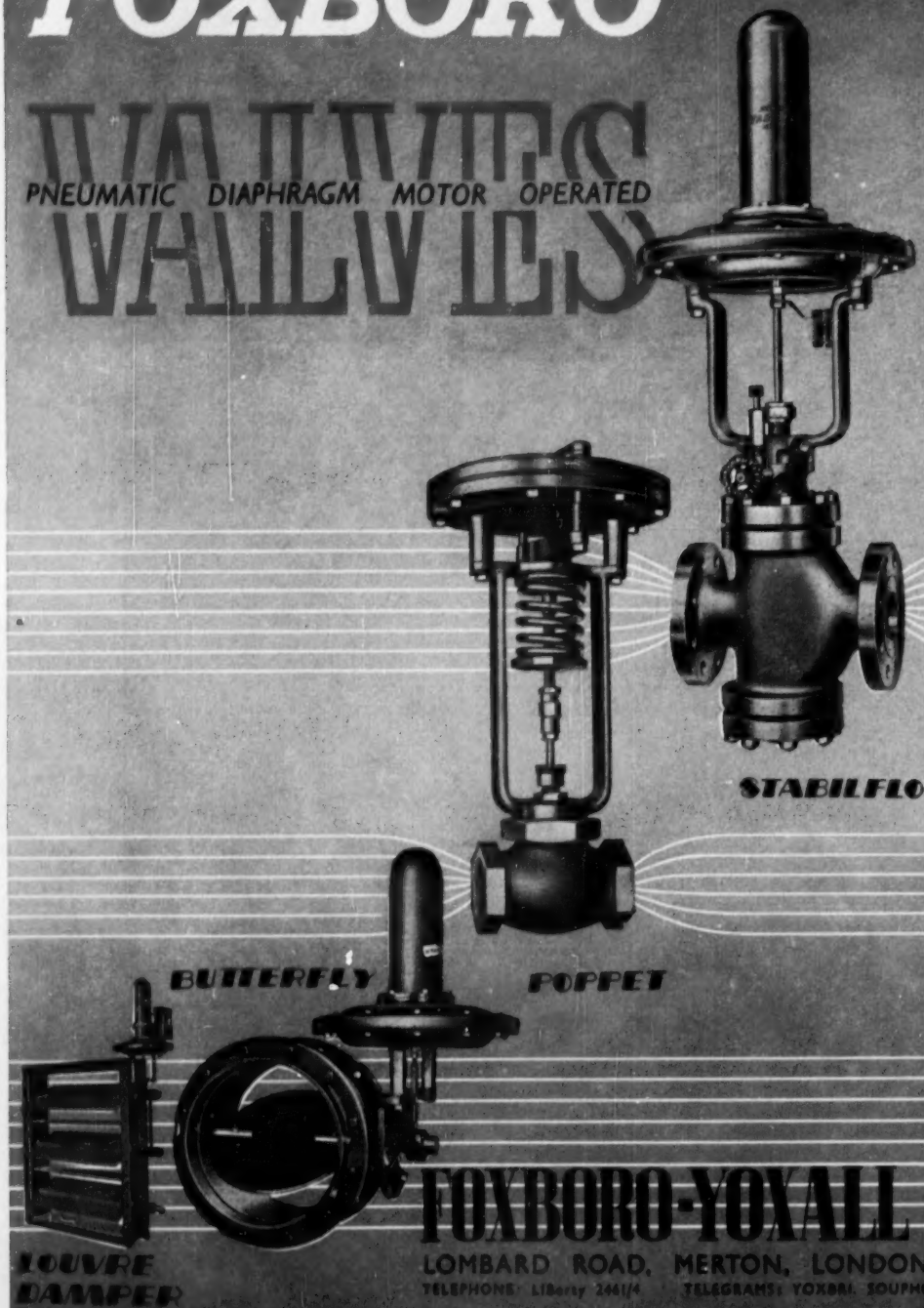

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